AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 31

1. SUBJECT CLASSIFICATION	A. PRIMARY: Agriculture	AE10-0000-G704
	B. SECONDARY: Agricultural economics--Korea Rep.	

2. TITLE AND SUBTITLE

Projections of product supply and factor demand under structural change for Korean agriculture, a systems simulation approach

3. AUTHOR(S)

Lee, Jeung-han

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1974	364p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Mich. State

8. SUPPLEMENTARY NOTES (*Sponsoring Organization, Publishers, Availability*)

(Diss.--Mich. State)

9. ABSTRACT

10. CONTROL NUMBER

PN-AAB-783

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Factor analysis
Korea Rep.
Production function
Projection
Simulation
Structures

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-2975 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

PROJECTIONS OF PRODUCT SUPPLY AND FACTOR DEMAND UNDER STRUCTURAL CHANGE FOR KOREAN AGRICULTURE: A SYSTEMS SIMULATION APPROACH

By

Jeung Han Lee

AN ABSTRACT OF A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1974

ABSTRACT

PROJECTIONS OF PRODUCT SUPPLY AND FACTOR DEMAND UNDER STRUCTURAL CHANGE FOR KOREAN AGRICULTURE: A SYSTEMS SIMULATION APPROACH

By

Jeung Han Lee

The primary purpose of this study has been to build a model of part of Korea's agricultural production system to be used as a component of the MSU/KASS model. Since the acreage response component has already been built, we have concentrated on modeling yield responses and factor demand of various crops in different regions. The basic emphasis of this study is on the yield effect of structural changes growing out of public policies, programs and projects designed to influence technology, institutions and people. It is recognized in this study that the major sources of productivity growth and development are structural changes.

One important byproduct of this study has been to show empirically how different disciplinary theories and techniques can be combined to model a complex system more precisely and accurately.

Useful neoclassical economics (modified or unmodified), development and growth theories are incorporated in this model, along with concepts, theories and descriptive information from other disciplines. The systems simulation approach has proven a useful technique in

integrating these diverse inputs into a yield determination component that can be incorporated into the larger KASS model for use in solving practical problems in the complex multidisciplinary system, which is Korean agriculture.

Economic development in agriculture is a complex process. An equally complex set of policy instruments is required to affect transformation of traditional agriculture. Thus, the model dealing with this complex system must be complex enough to measure important possible repercussions of complex policies, programs and projects. We have tried to meet comprehensiveness, consistency and balance, clarity, workability criterion in a sector model for planning purposes.

We specified a Cobb-Douglas type production function for every crop in each region under consideration with two basic kinds of variables: conventional inputs and structural change variables. The latter shift the yield function as well as the factor demand function. There are three different structural change variables. The first involves biological technology and human change (biological research and extension of its results). The second involves land and water development. And the third is the variable exclusively related to perennial crop production such as tree crop age cohort and residual effect of the conventional inputs used in the past. The first two structural change variables are generated mainly by the public sector. The rate of land improvement has been modeled by a high-order differential equation as a function of public investment, among others. The same is true for biological research and dissemination of its results. We have also recognized the existence of indigenous innovation among the leading farmers and by the agribusiness sector.

Jeung Han Lee

In order to estimate input usage for conventional production factors under the assumption of optimizing behavior, we have derived a factor demand function from the production function. In doing this, we have used several behavioral constraints. First, we have imposed a capital budget constraint modeled as a stepped supply function for credit. Second, various elasticities of factor demand have been adjusted, based on the direction, duration and magnitude of prices of both products and factors. The model allows adjustment to take place as a result of regional specialization, long-term profitability and for other reasons.

Once the relevant marginal rate of return to capital, as determined by the supply and demand relationship, was known, it was a mechanical process to project input usage and hence output. This permitted us to use accounting equations to compute the relevant aggregate variables.

After testing the model, through a series of sensitivity analyses, to determine whether it worked properly, we specified several policy experiments with variables. Then we made computer runs for each level for each policy variable and several different combinations of policy variable levels.

First of all, we identified quantitatively the sources of productivity growth for each crop in each region in more detail and precision than any study has thus far achieved.

The major conclusions drawn from the policy experiment computer run can be summarized as follows: First, important complementary relationship exist among the so-called conventional inputs, between these inputs and structural change variables, and between technological change and variables governing farmer incentives. The major determinants of conventional input usage, especially fertilizer, seem to be: (1) varietal change and (2) land and water development. Second, it appears that biological technology is a critical and leading determinant of yield growth. The second important structural change variable in productivity growth was found to be irrigation. Another important structural change variable defined in this model was found to be age composition change for tree crops.

Several values are important in the development of Korean agriculture. The simulated results of this study cannot be fully evaluated in terms of these performance variables unless the model presented in this study is linked with other components of the KASS model. For this reason, we have tried to evaluate alternative policies mainly in terms of food self-sufficiency and, in doing so, have assumed that the producer prices, areas allocated to each crop and consumption needs projected by the initial version of the KASS model correctly represent the future. Recognizing that biological technology involving varietal change is a crucial factor determining yield increases, we made several alternative assumptions about possible biological research accomplishments on the part of the Korean agriculture in order to project the simulated consequences of these alternatives.

In connection with this policy experiment, we have concluded that Korea is, at best, able to achieve her food self-sufficiency development goal in late 1970s. In the case of the worst biological research assumption, Korea was not able to attain this goal even by 1990.

The degree of food self-sufficiency depends substantially on the commitment of resource to improve biological technology.

All sets of conclusions reached here should be interpreted with reservations. This is so partially because various levels of interactions with other sectors or subsectors of Korean economy are not fully taken into consideration, partially because the model presented in this study needs some further refinements, and partially because the model's data base is rather weak. Needless to say, projections based on the model components developed herein and intended for use in evaluating public policies, projects and programs will be much improved when this component is linked with the rest of the KASS model.

Limitations of the present model and further study needs for improving it were presented. Needed additional study has to do with: (1) data improvement, (2) refinement of some model structures, and (3) linkage with other components of the KASS model.

Nevertheless, the version of the model presented here seems to represent the real world situation reasonably well; that is, the model seems to be capable of projecting yield levels and related conventional factor demand and projecting the consequences of various policy alternatives in terms of relevant criterion variables. With further refinement the model can be useful in evaluating policy alternatives for Korean agricultural development.

PROJECTIONS OF PRODUCT SUPPLY AND FACTOR DEMAND UNDER STRUCTURAL CHANGE FOR KOREAN AGRICULTURE: A SYSTEMS SIMULATION APPROACH

By

Jeung Han Lee

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1974

To my father, who laid the foundation,
but died without seeing the completion of this work.

ACKNOWLEDGMENT

Gratitude is given to Professor Glenn Johnson for the creative guidance he gave throughout the author's entire graduate program at Michigan State University. The author also wishes to express his appreciation to the members of his Guidance and Thesis Committees, Drs. Thomas J. Manetsch, thesis supervisor, George E. Rossmiller, Robert D. Stevens, William J. Haley, Michael H. Abkin and Victor E. Smith, for their assistance during his graduate program.

The author is grateful to the Agricultural Development Council Incorporated, for providing the fellowship that made the author's graduate program possible. Profound appreciation is extended to Professors Herman M. Southworth and A. B. Lewis, former associates of the Agricultural Development Council, and Earl O. Heady, who encouraged advanced graduate studies and arranged the fellowship for graduate programs at Iowa and Michigan State Universities.

The author also wishes to thanks to Drs. Tom Carroll, field leader, MSU KASS project, and Dong Hi Kim, Director, NAERI, and his staff for collecting data and other assistance.

Special appreciation is expressed to Sandy Clark, who edited the entire manuscript, To Enid Maitland, Judy Pardee, Ellen Vander Lugt and Patti Stiffler for typing the early draft and assisting with other secretarial matters, to Bert Pulaski for administrative services, and to Claudia Winer, Christopher Wolf, Keith Olson, James Williams and many others for assisting with the computer program.

Finally, a number of colleagues in the Department of Agricultural Economics contributed assistance and encouragement during the period of the author's graduate program. The author is appreciative of these acts of kindness and friendship.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

Table		Page
9.4	Model Response to Change in Extension Budget in 1985 . .	243
9.5	Model Response to Change in Product Price in 1985 . . .	243
9.6	Model Response to Change in Factor Prices in 1985 . . .	244
9.7	Model Response to Change in Government Credit Supply in 1985	246
9.8	Model Response to Change in Government Interest Rate in 1985	246
9.9	Model Response to Change in the Level of All Policy Variables in 1985	249
10.1	Sources of Yield Productivity Growth Rate (in Percent) for Rice in Region 1. Based on Medium Policy Level Set Specified in Table 9.1	260
10.2	Sources of Growth Rate of Fertilizer Use (in Percent) for Rice in Region 1, Based on Medium Policy Level Set Specified in Table 9.1	262
10.3	Sources of Yield Productivity Growth Rate (in Percent) for Fruits in Region 1, Based on Medium Policy Level Set Specified in Table 9.1	263
10.4	Hypothetical Planned Expected Research Results, in Terms of the Rate of Increase in Experiment Stations Yield, Adjusted by Proportion of Crop that could Advantageously Use Results (Biological Research Results are Assumed to be Forthcoming Earlier with the Same Amount Over a 15-Year Period of Total Accumulated Increase in Yield as that in Table 5.1	269
10.5	Hypothetical Planned Expected Research Results for Sweet and White Potatoes, in Terms of the Rate of Increase in Experiment Stations Yield, Adjusted by the Proportion of Crop Area that could Advantageously Use Result	275

LIST OF FIGURES

Figure | Page

Figure Page

PREFACE

> Basically, this transformation is dependent on investing in agriculture. Thus it is an investment problem. But it is not primarily a problem of capital supply. It is rather a problem of determining the forms this investment must take, forms that will make it profitable to invest in agriculture [Schultz (S.2, p. 4)].

The report presented here is a case study of agricultural development planning, based on a comprehensive and consistent agricultural sector analysis model for Korea. For the study to be manageable, the focus is primarily on the production side of agricultural development. The model presented in this study is a subsector model of the Korean Agricultural Sector Simulation Model constructed and being improved jointly by a Michigan State University agricultural sector simulation team and National Agricultural Economics Research Institute, Ministry of Agriculture and Fisheries, Republic of Korea.

The initial version of the Korean Agricultural Sector Study (KASS) model is reported by Rossmiller, et al. [R.7] in 1972. Since then, there have been several ongoing studies to refine the KASS model. This study is one of those attempts. Since the author is oriented toward production economics, the attempt is to improve the production component of the KASS model.

The first refinement attempt for the production side was to build in a linear programming component for the KASS simulation model. The purpose was to guide resource allocation among various economic activities within and among regions, as will be reviewed in the discussion of the KASS model and its linear programming model component in Chapter II.

The KASS team concurrently conducted a study on investment priorities in the Korean agricultural sector, as reported in Ferris, et al. [F.5, 1972]. Public investments are made to induce changes in technology, institution or human nature. Such changes alter the production possibility frontier, consumption patterns, producer incentives or a combination of these. In a planned or directed economy where the public sector plays an important role, public investment is vitally important in generating changes in technology, institution and human nature. For this reason, a consistent, comprehensive sector model must link production, market, consumption or other components of a sector model to the public sector.

Public investment cannot be determined without knowing the behavior of the private sectors. Likewise, the behavior of private sectors cannot be explained or analyzed without knowledge of the public investment pattern.

This study first models two distinct components: one for the public investment subsector and the other for the farm micro production subsector. The former subsector model is intended to explain how technological, institutional and human changes are generated by means of public investments. The latter subsector models the farm production system, including factor demand and product supply, and is based on various concepts from neoclassical economic theories.

By linking two subsector models, it is possible to explain how the farmer's decisions and hence production and supply response are affected by public decisions on agricultural policies, programs and projects. However, linking the public investment sector, in addition to the other public decision, with the farm micro production subcomponent alone provides the public decision-maker with only a limited amount of information as a basis for the public policy evaluation. In addition, the farm micro production subcomponent must be linked to the rest of KASS simulation model, to fully evaluate various types and levels of public policies.

It is possible and even advantageous to decompose a large system so that each subcomponent or a group of subcomponents can be modeled and tested separately.

The first phase of the present study is restricted to modeling the two subcomponents mentioned above. After modeling these two subcomponents, a test is made to see whether the model presented in this study works properly. This is done by making a number of projections of the farm micro production variables for various alternative courses of action public decision-makers can take.

There are a number of variables whose time paths would be interesting to the public resource administrator or the researcher. The main variables this study will generate time paths for are: (1) demand for several classes of farm inputs per unit of land, including labor by seasons, for various crops under consideration, (2) variable production costs for each crop, (3) production level of each crop per unit of land (yield), (4) various classes of improved land, and (5) various sources of what is often called the total factor productivity change.

The first four categories of the model outputs will become direct inputs to the linear programming component of the KASS farm resource allocation model, as either input coefficients, components of objective function coefficients, or capabilities of the resource constraints. In a sense, the present model is designed to make almost all important components of the linear programming component endogenously determined in response to public policies, programs and projects.

The analytical framework used to describe the system, the public investment and farm micro production subsectors is the so-called systems simulation approach. There are a number of reasons for choosing this particular analytical framework for modeling this system. First of all, the lagged adjustment of the economic system to a change has long been recognized by researchers. Second, the interaction among various system subcomponents has also long been recognized among social scientists. It is a well known fact that Adam Smith's notation of an "invisible hand" implies this interaction among consumers, distributors and producers. Relationships between variables in agriculture and between agriculture and the nonagricultural sector, including the public sector, are complex and dynamic, however. Third,this complex and dynamic system may not be successfully modeled by a linear economic model.

Thesis Organization

After this introduction, it is now appropriate to describe the organization of this thesis. It is divided into four parts and one appendix. In Part I, we will review some useful economic theories and models of economic development and growth in agriculture, as well as theories and models of agricultural sector analysis and planning. Second, after introducing the global model of the KASS, we will examine the need to refine it and its farm resource allocation subcomponent model, which is a linear programming model. On the basis of this examination, we will propose a new component to supplement the existing system model of the KASS.

In Part II, we present the mathematical structure of the new component composed of the public investment and farm micro production subsectors. Each subsector is discussed in two chapters. The former subsector model deals with land and water development and research and extension separately, both having public investment as a unique input. The farm micro production subsector models factor demand and product supply structures. Both receive outcomes of the public investment subsector, as well as exogeneously determined policy instrumental variables such as prices, credit, etc., as inputs. The outcome of factor demand, of course, becomes an input to the product supply.

In Part III, we present the result of the analysis of the model presented here. Based on the model presented in Part II, policy experiments are undertaken after verifying the model. The main purpose of this experiment is to provide public decision-makers with information useful in formulating political decisions.

In Part IV, policy implication and conclusions reached as a result of policy experiments for the sector model are discussed. We also will briefly consider further study needs for the current model to be used for actual planning purposes.

Appendix A contains a computer program of the model, written in FORTRAN language. All initial conditions and parameters used for the initial run are included, in addition to all other subroutines needed to support the main subroutines.

PART I

BACKGROUND AND PURPOSE OF THE STUDY

CHAPTER I

THEORIES IN AGRICULTURAL SECTOR ANALYSIS AND PLANNING

Introduction

Chapters in this part more or less introduce the chapters that follow. Any kind of economic sector model must be based on some useful theories of economic development and growth. Underlying or background economic theories for the present sector model are reviewed in Chapter I. Unfortunately, there is no single set of theories or methodologies that can be borrowed directly for modeling system under consideration. Thus, what is needed is to creatively synthesize somewhat eclectically theories from various disciplines: neoclassical or modified neoclassical economics, systems science, econometrics, agronomy, and so forth.

As mentioned in the preface, modeling the system to be described in this study will refine the structure of the existing global system of the KASS model. To provide a background of the present study, it is necessary to introduce the structure of the KASS model. In other words, while we review the initial version of the KASS model, we examine how the KASS model needs to be refined or modified to be more comprehensive and consistent as a sector model. However, the present effort to refine the KASS model is restricted to the production side. In Chapter II, we will first review the overall structure of the KASS model and then its linear programming farm resource allocation component.

Having learned the necessary or useful theories or methodologies from various disciplines concerning a sector analysis, and the structure of the existing KASS model to be refined, we are ready to propose a modified version of the KASS model. In Chapter III, we will discuss the purposes and objectives of this study, along with its scope.

The purpose of this chapter is to briefly review some of the formal economic growth models and theories of economic development in agriculture and some of the formal models of agricultural sector analysis and planning. Since the emergence of economics, the economist has been concerned with economic growth and development. Instead of trying to review all relevant models or theories, we confine ourself to reviewing those modern models and theories that provide some background to our study.

Aggregate Production Function Studies

It seems that the Harrod-Domar model is a logical starting point for the modern growth theory,[1] which is essentially a sort of long-run equilibrium theory. However, this model seems to oversimplify the analysis of the economic growth process. A crucial assumption made in this model is that capital and labor are combined in fixed proportions. This implies that these factors of production cannot be substituted. In other words, the elasticity of substitution between them is assumed to be zero, which is unrealistic. Thus, according to this model, the maximum growth rate is restricted to a minimum of the rates of labor

---

[1]For a comprehensive survey of modern formal growth theories, see Hahn and Matthews [H.1].

force growth and capital accumulation, and steady-state growth requires these two rates to be equal to each other, which is called the warranted rate of growth.

The oversimplification of this model has induced what is called the neoclassical growth theory, or the aggregate production function approach to growth. Solow [S.10] criticizes the Harrod-Domar model: "A 'crucial' assumption is one on which the conclusions do depend sensitively, and it is important that crucial assumptions be reasonably realistic." Then he [S.11] presents an alternative growth model, which has simulated a variety of studies on technological change. The type of production function studied is essentially the Cobb-Douglas type, assuming constant returns to scale, with two inputs, labor and capital. One of the critical assumptions he makes is that, after defining technical change as a short-hand expression for any kind of shift in the production function, the time-varying intercept of the function permits measurement of this technical change.

Let us denote the output level by Q, capital input by K, labor input by L and the intercept by A. The corresponding Cobb-Douglas function is:

$$Q(t) = A(t)k^{\beta}(t)L^{1-\beta}(t)$$

where β is production elasticity of capital. By differentiating the above equation totally with respect to time and dividing by Q(t), we have:

$$\frac{\dot{Q}(t)}{Q(t)} = \frac{\dot{A}(t)}{A(t)} + \frac{\dot{K}(t)}{K(t)}\,\beta + \frac{\dot{L}(t)}{L(t)}\,(1-\beta)$$

where dots indicate time derivatives. He makes another assumption in his study: factors are paid their marginal value product. As this implies that the production elasticity of a factor is equal to its factor share, it assumes the system is in competitive equilibrium. When the model is applied to historical time series data, all variables except $\dot{A}(t)/A(t)$ are known. Thus, this unknown term can be computed. This is the essence of his initial study on technical change [1957]. The term $\dot{A}(t)/A(t)$ once again represents a degree of technical change and is called total factor productivity change. In this particular example, technical change is computed as a residual. However, it is possible to estimate it directly, if desired by fitting the following function, for example:

$$Q = A\,K^{\alpha}\,L^{\beta}\,e^{\gamma t}$$

when γ measures one type of technical change.

Is this type of growth model appropriate for making a policy recommendation? This formation of economic growth model has been criticized as a formal growth model on two grounds. Nevertheless, it shouldbe recognized that Solow's pioneer work on this subject has laid a foundation for subsequent research on economic growth. The first and most serious criticism of this model has been the assumption on disembodied technological change. The second is on a property of the Cobb-Douglas production function itself, a unitary elasticity of substitution between factors.

The assumption on treatment of disembodied technological change is attacked by many scholars (Schultz [S.2], Griliches [G.12], Nelson [N.4], Denison [D.8], etc.). That is, technical change in Solow's initial pioneer work is treated as an unexplained residual. Schultz calls it a measure of our ignorance. Griliches attacks it by pointing out that one of the objectives of growth theory should be to reduce the unexplained residual. Denison claims that one purpose of studying the aggregate production function is to provide a menu of choices available to increase the growth rate. After this type of criticism, the so-called embodied technical change type of aggregate production function study has been increasing.

Solow [S.12] in a later article assumes technical change embodied only in the capital stock. Denison [D.8] separates out the contributions of a large number of variables, where labor input is adjusted for quality. Advances in knowledge and economies of scale are used to explain an increase in output per unit of input. Griliches [G.12] disaggregates capital inputs in more detail to derive an aggregate production function for U.S. agriculture. One variable used to explain customarily unexplained residual is education. Hayami and Ruttan [H.9, p. 105-106] adopt essentially the same type of approach to estimate aggregate production functions on intercountry data.

What would be the implication of all these results for policy prescription, especially for the LDCs? Of course, education or advances in knowledge will surely have an impact on the long-run growth of any country. The policy-maker in most LDCs is more interested in short-run problems for one reason or another--to get rid of the poverty at hand, to survive politically, and so on.

Are these variables only policy variables for economic growth in agriculture or another sector of an economy in the long-run as well as the short-run? Yamado's [Y.1] model is somewhat suitable for policy prescription in the sense that he includes so-called conventional as well as nonconventional inputs, which are separated out more or less in detail, although disaggregation is not very satisfactory.

Any sort of the aggregate production function previously studied may be criticized on at least three grounds as a guide of policy direction, although they have been an excellent academic exercise. They provide limited amounts of information, from which specific policies, programs and projects toward economic development and growth are formulated in the long-run as well as the short-run. The other criticism is that little interaction with other sectors of the economy is taken into consideration in this approach.

By what kind of mechanism would the so-called conventional inputs be changed over time? An improvement in factor supply from the nonfarm economy? An increase in the so-called nonconventional input level or structural change? How would structural changes take place? What would induce or generate them?

The third possible criticism has to do with the fact that economic growth is not synonymous with economic development. The terms "growth" and "development" cannot be used interchangeably. Economic growth may be defined as a continued increase in per capita income or production. Economic development is, however, more than that. An economy can grow without development. According to Seers [S.5]:

> "The questions to ask about a country's development are therefore: What has been happening to poverty? What has been happening to unemployment? What has been happening to inequality? If all three of these have declined from high levels, then beyond doubt this has

"been a period of development for the country concerned. If one or two of these central problems have been growing worse, especially if all three have, it would be strange to call the result "development,' even if per capita income doubled. . . .A 'plan' which conveys no targets for reducing poverty, unemployment and inequality can hardly be considered a development plan."

Dorner [D.10] views development process as follows:

"People are beginning to realize that development is more than capital, investment, and markets. It is a complicated process of institutional change, redistribution of political power, human development, and concerted, deliberate public policy efforts for redistributing the gains and losses inherent in economic growth."

He questions the appropriateness of present theories in this way:

"Present theories provide little insight even on U.S. issues: environmental quality, poverty, race relations, a more acceptable distribution of economic and political power, congested cities, rural development, automation and basic changes in the structure of resource ownership. Present theories do not seem to encompass these issues"

Further, he questions:

". . .are the value questions of public policy subject only to political compromise or the dictates of dogma coercion and personal tastes?"

Seers, in connection with this question, writes:

"The starting point is that we cannot avoid what the positivists often disparagingly refer to as 'value judgment.' 'Development' is inevitably treated as a normative concept, as almost a synonym for improveme To pretend otherwise is just to hid one's value judgments."

In fact, development planning cannot be free from value judgment or normative information. Rossmiller, et al. [R.7 , p. 47] feel that, although these values may not be explicitly stated, a review of policies, programs and projects established, and interactions with policy-makers can lead to identification of normative knowledge or value constellations considered important in the planning process. They insist that "Government achieves values through policies designated to achieve specific goals while hopefully minimizing the adverse effects of attaining those goals."

Micro Economic Models of Development

Now let us review some micro economic models dealing with technological, institutional and human changes toward economic development and growth. There are a number of these theories and models.

Often-cited examples are Schultz [S.2], the "high-payoff input model" named by Hayami and Ruttan [H.9, p. 39], and their own "induced development model." The key element of both models is supply conditions of a new, improved, nonconventional but profitable production factor, material or immaterial. A significant difference between these two models seems to have to do with how a new and improved factor is supplied. Hayami and Ruttan [H.9, p. 42-43] insist that Schultz's model is incomplete:

> "The high-payoff input models, as developed by Schultz in Transforming Traditional Agriculture, remain incomplete as a theory of agricultural development, however. Typically, education and research are public goods, not traded through the market place. The mechanism by which resources are allocated among education, research, and other alternative public and private sector economic activities is not fully incorporated into the Schultz model. The model does treat investment in research as the source of new high-payoff techniques. It does not explain how economic conditions induce the development and adoption of an efficient set of technologies for a particular society.

> Nor does it attempt to specify the process by which factor and product price relationships induce investment in research in a particular direction."

The essence of the "induced development model" advanced by Hayami and Ruttan can be summarized by quoting a few sentences:

> "A major extension of the traditional arguments is that we base the innovation inducement mechanism not only on the response to changes in the market prices of profit maximizing firms but also on the response by research scientists and administrators in public institutions to resource endowments and economic change. We hypothesize that technical change is guided along an efficient path by price signals in the market, provided that the prices efficiently reflect changes in the demand and supply of products and factors and that there exists effective interaction among farmers, public research institutions, and private agricultural supply firms." [H.9, p. 57].

They further hypothesize that "the institutions that govern the use of technology or the mode of production can also be induced to change in order to enable both individuals and society to take fuller advantage of new technical opportunities under favorable market conditions." [H.9, p. 59-60].

Let us evaluate this induced development model. One way to do this is to see what other scholars think about the model. Indeed, there are numerous criticisms of this model on several grounds. A representative one is that made by Beckford [B.4]. He points out that

> ". . .the first point for us to note is that, contrary to the title of this paper, Ruttan and Hayami are not concerned with agricultural development at all . . .Their model is, therefore, more appropriately a model of agricultural growth rather than of agricultural development . . .the growth of agricultural output and productivity

"may be a necessary,[2] though certainly not a sufficient, condition. . .substantial growth of agricultural output is accompanied by no change in the material welfare of the majority of people involved in the process of that growth. . .there is always a strong possibility of the phenomenon of growth without development."

It seems that Beckford is right in his conclusion. To prove this point, let us remember what happened in Korea or Taiwan before World War II since Japanese occupation. Despite a substantial increase in agricultural productivity, thanks to an "extensive development assistance" [H.9, p. 52] from Japan innumerable people had to live on wild vegetables and barks. Is that economic development? Is that the result of "extensive development assistance" and "effective interaction" between Japanese rulers and Korean or Taiwanese farmers?

A phenomenon of exploitation exist not only between countries, but also within a country. There is a substantial amount of literature that insists Japanese farmers were exploited to serve industrialization. If so, is that a consequence of an "effective interaction" between the rulers and farmers?

Let us go back to Beckford:

"The one-to-one association between the society's factor endowments and relative factor prices ignores two fundamental characteristics of underdeveloped countries. One is the marked divergences between private and social costs and benefits . . .and the other is duality. . .that distorts the relative factor prices faced by different producers within the same economy."

---

[2]In this respect, Beckford seems to hold an extreme position, since the growth of agricultural output and productivity is certainly a necessary condition for development.

Other worthwhile comments by Beckford are:

> ". . .the Ruttan-Hayami model seem to imply that what is good for the firm is good for the industry. . . Given the inelastic demand for farm products, expansion of output for the individual farm-firm produces different results from the expansion of output for all farm firms."

He also says:

> "It is totally impossible to explain institutional reform in purely economic terms, as Ruttan-Hayami have tried to do."

There are many comments on the hypothesis of induced institutional change. Wood [W.5], among others, feels that

> ". . .institutional reform should appropriately be viewed as a planned, strategized, and integrated part of any significant agricultural development effort among the LDCs."

and adds that,

> ". . .institutions which are the creation of man for the purpose of accomplishing given objectives, cannot now--if they ever were--be treated as a 'response.' The institution or organization is the tool of society to achieve some felt need, be it religious, defense, or for economic betterment. Institutions are part and parcel of the development process--if development is to take place."

Indeed, institutional change is a political process, having to do with economic considerations as well as noneconomic ones, such as national security, political survival, etc. The latter consideration is perhaps prevalent. Thus, most of them are far from purely economic in nature.

What would the policy implication of the induced development hypothesis be? After reemphasizing the role of economic forces in the resource allocation decisions of both private sector firms and public sector institutions, Hayami and Ruttan conclude that,

> "In most developing economies the market systems are relatively underdeveloped. A major challenge facing these countries in their planning is the development of well-articulated market systems, capable of accurately reflecting the effects of change in supply, demand and production relationships. An important element in the development of a more efficient market system is the removal of the rigidities and distortions resulting from government policy itself. . ." [H.9, p. 306].

Let us go back to discussion of theories of actions attainable under the existing system. Schultz's high-payoff input model, as its name implies, is primarily concerned with improving supply conditions of the new improved profitable production factors. Heady and Tweeten [H.19, p. 2] visualized even earlier that "while the problems of agriculture are directly those of commodity supply and price, basically they are problems of resource demand and supply."

Thus, the input market as related to agriculture is especially important.

> "Economic growth from the agricultural sector of a poor country depends predominantly upon the availability and price of modern (nontraditional) agriculture factors. The supplier of these factors in a very real sense hold the key to such growth" [Schultz (S.2, p. 145)].

Agricultural development can be characterized as the process of substitution of farm-produced or traditional production factors by off-farm-produced factors. Thus, major policies for transforming traditional agriculture to economic development and agricultural growth may be summarized as policies, programs or projects showing how these modern, new, improved or nontraditional inputs can be supplied cheaply. These involve sufficient producer incentive with due account of uncertainty or risk. These modern inputs are often classified in connection with their supply conditions. Hayami and Ruttan [H.9, p. 40] implicitly categorize Schultz's high-payoff input into (1) varietal or other biological inputs, (2) technical inputs supplied by the industrial sector, and (3) farmers' human factor.

Mellor [M.11] classifies the modern inputs under the heading of the scarce resource as follows: (1) institutions to provide incentives, (2) research to develop improved production possibilities, (3) production facilities for physical inputs of new and improved forms, (4) institutions to service agricultural production, and (5) education to help farmers make choices.

However, as Hayami and Ruttan point out, the high-payoff input model advanced by Schultz and others does not explicitly explain how these new factors are supplied. Nevertheless, this high-payoff input model can be more generalized in the sense that the modern inputs can be either induced or generated to be supplied purposively. The public sector can invest for the private sector, which supplies the farm sector with the modern inputs for example. This likely leads to factor price distortion or rigidities of resource mobility. Therefore, this tends to involve a malallocation of the nation's resources in the short run. This policy is not necessarily bad, however, if it is better for the total system of the economy in terms of developmental goals or values.

Development Strategies

Next, we should ask what strategies should be used to modernize traditional agriculture. In connection with this issue, a bottleneck or ad hoc project-by-project approach and an integrated approach can be distinguished. Many development theorists seem to agree that a complementary relationship exists between modern inputs and incentives, with due reservation for uncertainty and risk. In addition, the former approach is criticized because it tends to rely exclusively on internal return rates as decision criteria rather than including a broader range of objectives, such as employment, income distribution, etc. [Manetsch, et al. (M.4), Eicher, et al. (E.2) and many others].

Adams and Coward [A.4] put the basic philosophy of the integrated approach this way:

> "Small farmers face a very complex set of problems which must be treated simultaneously by an almost equally complex set of policy instruments."

Mosher [M.23, M.24, M.25] among others, has been a strong advocate of this approach. Mosher [M.25] distinguishes policies, programs and projects directly related to agricultural development from those directly related to rural development. His classification of simultaneous or integrated activities for overall agricultural development includes: (1) Research, (2) producing or importing farm inputs, (3) rural agri-support activities, (4) production incentives, (5) land development, and (6) training agricultural technicians.

For rural or nonagricultural development activities this includes a variety of activites, such as community development, home economics, health, schooling, family planning, etc. According to Mosher, all of them (his classification) have two characteristics in common. First, each project is limited to a specific land area, at least in the beginning. Second, each project is (or should be) limited to elements not already present and reasonably effective in the project area. Thus, any combination of these activities is possible, depending on specific location and objectives.

This integrated policy approach is becoming popular among the LDCs. The new village movement in Korea directly reveals this approach. Other examples of this approach, often known as a package-of-practices strategy, are the Comilla Project in Bangladesh (Stevens [S.17], among others), the Intensive Agricultural Development District Programs (IADP) in India (Malone [M.2], among others), and the Pueblo Project in Mexico (Myren [M.29]).

The agricultural sector is only one component of the total system of a nation's economy. This implies that agricultural sector interacts with the rest of the economy in terms of production and distribution of products and factors. This interaction is well documented by Johnston and Mellor [J.2, M.11], Nicholls [N.9], among many others. This discussion in turn involves approaches of balanced or unbalanced growth or leading sector analysis in determining investment priority. Nurkse [N.10, p. 4-5] emphasizes the necessity of balanced growth as a condition for eliminating the "vicious circle of poverty" in the LDCs. Similarly Rosenstein-Radan [R.6, p. 57-67] backs balanced growth by advancing a "big push" hypothesis.

The balanced growth model is attacked, however, by Hirshman

[H.25, Ch. 3], among others, on the ground that this model ignores a lead and lag relationship that induces investment activities in the lag sector by eliminating the bottleneck sector. The classical dual sector model advanced by Lewis [L.16] emphasizes the relative importance of the role of industrial development. Contrarily, Ranis and Fei's classical dual sector model [R.1] incorporates the role of agricultural production growth. Lewis and Ranis and Fei's pioneering works seem to have paved the way for modern sector analysis.

Before reviewing sector models in various levels, we should discuss the controversy on balanced or unbalanced growth. According to Nicholls [N.9],

> "The rapidly growing literature on the history, theory, and policy of economic development has perforce recognized the dominant place of agriculture in the underdeveloped countries and has generally concluded that economic development requires that vast numbers of rural people shift out of agriculture. This literature has also usually agreed that substantial industrialization is necessary if this redundant agricultural population is to find more productive nonagricultural employment, thereby permitting those who remain in agriculture to reorganize their farms into more efficient, larger-scale, mechanized operating units."

Nicholls feels, however, that "within a sufficiently long-run context, these conclusions are beyond for virtually any underdeveloped country." The problem arises because any economy has by definition a limited amount of resources to be used for economic development. In allocation of investment, therefore, the agricultural sector competes with the rest of the economy.

The agricultural fundamentalist believes that first the agricultural sector has to be sufficiently developed, whereas the industrial fundamentalist believes that first priority should be given to the industrial sector. Balanced growth or unbalanced growth? In unbalanced growth, which sector is to lead and which is to lag? Nicholls seems to have the theoretical solution to this controversy. Having agreed that substantial industrialization is necessary for economic development, he adds that,

> "However, as guides to the establishment of short-run planning goals and priorities--particularly as between agricultural and industrial development--they are, in my opinion, often misleading if not completely fallacious

He continues,

> ". . .instead, I believe that the role of agriculture in economic development depends heavily upon the stage of economic history in which a particular nation finds itself and, especially at the time that economic progress first becomes a major social aspiration, upon the ratio of agricultural land to population."

After reviewing the western country's experience in economic development process, he concludes that:

> ". . .industrial development was heavily financed by the exploitation of agriculture and rural people . . .agriculture could be thus exploited only if it first produced a surplus which was there for exploitation."

After attacking India's heavy emphasis on the industrialization effort, including its supporters such as Lewis, Higgins, Coale and Hoover, etc., he remarks that the potential of India's agriculture as a source of economic growth is great if modest investments are made, and concludes that, "until underdeveloped countries succeed in achieving and sustaining a retrievable food surplus, they have not fulfilled the fundamental precondition for economic development."

This thesis of agricultural growth as the prerequisite of economic development seems to have increasing popularity. Having emphasized the basic and general industrial sectors during the first and second five-year economic development plans for 1962-1971, Korea shifted its emphasis to developing the agricultural sector more fully in the third five-year economic development plan period, 1972-1976. According to the presidential statement on the third five-year economic development plan, "During the plan period, top priority will be given to the agricultural sector so that the fruits of our economic development will be equally distributed among the entire nation. . ." [Government of the Republic of Korea (G.2)].

The Deputy Prime Minister and Minister of the Economic Planning Board states in the above source that:

> "In addition, the third five-year economic development plan targets emphasize the urgent tasks of realizing self-sufficiency in major food grains, improving the international balance of payments. . ."

The consequences of the first and second five-year plans in Korea, which focused unduly on industrialization, will not be examined here. However, it is pointed out that it seems right for the nation's top public decision-makers to be willing to correct the existing unbalance and furthermore, to recognize the necessity for more emphasis on agricultural development as a precondition of sound and sustained overall economic development of the nation.

Sector Analysis Models

Let us go back to models of sector analysis. The primary purpose of a sector analysis is to describe how a system works. A system can be conceptualized as composed of major industries such as agriculture, industry, etc., or as composed of major components within an industry, in terms of their functions or locations. In general, a system can be defined as consisting "of a group of objects that can interact with one another and are assembled in a manner intended to achieve a desired objective." [Cooper and McGillan (C.8) p. 2].

The key words are "objects" or "components" and "interaction." In principle, a national economy can be treated as a system and modeled comprehensively and consistently in detail, including all major sectors and their subsystems. Since there would probably be no general analytical solution to this complicated system, the system can be simulated to examine what would happen to the nation's economy in terms of development goals such as growth rate, employment, income distributions, etc., based on alternative public policies or other exogenous variables. And then, the specific public policies, programs or projects that are right can also be derived.

However, the sector models customarily advanced are simplified two-sector models or their extension. It is well known that Lewis' model [L.16] is an initiation of a dualistic economic development, very similar to a model advanced by Nurkse [N.10], where capital formulation takes place with disguised unemployment in agriculture through public work. Ranis and Fei [R.1] advance another dual-sector model, which extends Lewis' model to incorporate analysis of the role of agricultural sector. These models seem to suffer from the assumption that continued over supply of labor or disguised unemployment in agriculture implies zero marginal productivity of labor. A neoclassical dual-economy model by Jorgenson [J.22] drops two assumptions made in the classical dual-sector model; that is, the assumptions of (1) zero marginal labor productivity and (2) an institutionally determined wage rate in agriculture.

Harris and Todaro [H.4] advance another two-sector model where they assume a politically determined minimum urban wage at substantially higher levels than agricultural earning, which is determined by competitive market forces. This is a direct reversal of the assumptions made in the classical dual-economy models.

The explicit variables of all these two-sector models have been employment and migration or transferring labor force, and the leading sector has been the urban or industrial sector. However, the Mellor [M.14] model seems to treat the agricultural sector as the leading sector and focuses specifically on the effect of increased agricultural output through technological change on employment and income.

To overcome the shortcomings (the limited usefulness of two-sector models) and come somewhat closer to reality, many researchers have extended the conventional two-sector models. Reynolds [R.4] proposes a four-sector model in which the traditional sector is divided into agricultural and urban trade-service sectors, and the modern sector into industrial and government sectors. Byerlee and Eicher [B.17] advance another four-sector model composed of (1) small-scale agriculture, (2) small-scale rural nonfarm, (3) small-scale urban, and (4) large-scale urban sectors. Again, both models' central concern is employment, viewing that successful development is best defined in employment terms rather than in terms of output alone.

Oshima [O.4] states that,

> "It is not difficult to frame job creation projects which will increase employment substantially, but to do so without reducing existing growth rates of national product is not easy, but even more difficult is the task of formulating employment policies which would increase existing growth rates."

He adds that,

> "For the basic purpose of the economy is to create income not jobs. (The 'best of all worlds' is one in which all the income is produced with no employment, and the 'worst of all worlds' is one in which no income is produced under conditions of full employment." It is, therefore, necessary to study employment in relation to income. . ."

It seems that the problem has been that the correlation between income and employment growth rates has been less than one, which implies that, despite substantial industrialization in many countries, the labor force has not been absorbed as much as expected or desired. Another aspect of this problem is the fact that the fruit of economic growth in many developing countries has not been shared with the mass of people. A skewed income distribution is often supposed to be necessary for economic growth, based on an assumption that the higher-income class has a higher marginal propensity to save; thus, a trade-off relationship is conserved to exist between income and employment or income distribution.

Viewing that capital-intensive industrialization need not cause unemployment under certain conditions, which increase the employment multiplier, Oshima [O.5] concludes that these conditions would be hard to establish in Asia, and therefore a balanced development of the capital-intensive and labor-intensive sectors is necessary. His model consists of three sectors: nonagricultural capital-intensive and labor-intensive sectors and a labor-intensive agricultural sector.

Oshima's trisector framework is intended to resolve difficulties involved in the trade-off relationship. That is, by developing labor-intensive sectors, income and employment are generated by the interaction of these sectors with the capital-intensive sector in terms of effective product demand.

Sector Planning Models

What we have reviewed thus far are theoretical models from which some basic broad quantitative policy direction can be drawn. While a sector analysis is intended to explain how a system works, its ultimate purpose is to help the public decision-maker in formulating economic development planning through policy analysis of sector models. It seems that in the developing countries, demand for quantitative analysis and policy recommendations is increasing rather rapidly. The economic development process involves a complex set of problems: the development goal would be usually more than one, the alternative way to achieve these development goals would also be more than one set, the scarce resource or limiting factor would be more than one, various components are interacting with each other with a lead-and-lag relationship, and the resources to be used must be consistent with what is available as well as with intermediate needs. The qualitative theoretical model can hardly handle this complex set of problems and subproblems.

According to Vernon [V.2],

> "It is only a decade or so since economists have learned how to set up and manipulate comprehensive models of a national economy. And it is only a decade or so since the less-developed economies have begun to turn to national planning as a means of helping them to achieve their economic aims. The two activities have now flowed together, intermingled, to a degree which sometimes makes them appear indistinguishable to layman. Yet they are clearly separable concepts."

Nevertheless, he adds,

> "According to the emerging norms, no country can be said to engage in national planning unless it has a well-articulated plan whose contents satisfy certain minimum criteria."

He continues,

> "It (plan) must satisfy at least two requirements: comprehensiveness and consistency."

By "comprehensiveness," he means that it (plan) explicitly states a set of output and income targets, and it must trace out, in quantitative terms, the path between these targets and the necessary inputs. For consistency, he illustrates the concept instead of defining it, by a consistency test between the composition of goods produced and demanded, between the saving implied and investment required, etc.

He adds his third criteria--optimality--this way:

> "In the past few years another major conceptual advance appears to have been shaping, soon perhaps to become still another prerequisite for an adequate plan. According to the new concept, a national plan must not merely be demonstrably comprehensive and consistent in all its parts; it must also make the best possible use of a country's scarcest resources, whatever they may be. Accordingly, the acceptable plan may be tested in the future not only by the standards of comprehensiveness and consistency but also by that of optimality."

His definition of comprehensiveness appears unsatisfactory to this author, however. His definition seems to imply the other type of consistency between the end and means, and because, by definition, any plan, whether or not it is comprehensive, involves a statement on the end and means. Otherwise, it is not a plan at all. Instead, this author would like to suggest the other definition of the term. That is, a plan can be said to be comprehensive if it counts all possible important interactions among various components of the system under consideration. Therefore, it can be said for a plan to be comprehensive, the model from which the plan has been formulated must integrate all major interacting components and their subcomponents of the system.

Thorbecke [T.2] put it this way:

> "The purpose of a sector model should be to capture the most important structural and behavioral relationships within agriculture and between agriculture and the rest of the economy, on the one hand, and to be potentially useful to the policymaker as a planning tool to help select and formulate a sector program, on the other hand."

Why plan after all? According to Griffin and Enos [G.4, p. 21]

> ". . .the case for planning rests on the inability of the price mechanism to ensure growth, efficiency and equality. The more difficult the problems confronting development, the less adequate will be a policy of nonintervention, and the greater will be the need for planning."

In a footnote, they say,

> "Some authors believe they have found a correlation between planning and slow growth and have attributed the latter to the former. This, of course, is nonsense. Planning is not a cause of slow growth but a response to it."

On the other hand, Todaro [T.3, p. 1], views the nature of planning as follows:

> "Economic planning may be described as the conscious effort of a central organization to influence, direct, and, in some cases, even control changes in the principal economic variables of a certain country or region over the course of time in accordance with a predetermined set of objectives."

He remarkes on the nature and purpose of planning specific in capitalist economies in this way:

> "The instruments of policy are active but indirect. They are active to the extent that they push the economy in a desired direction. They are indirect in the sense that they are intended merely to create favorable conditions in which private decision makers will be influenced to behave in a manner conducive to the continuous realization of stable economic growth."

Griffin and Enos recognize the limitation of a price mechanism, but imply that there is always a positive correlation between economic planning and economic growth, no matter what the plan. Let us see what Dandekar [D.2] says about a plan that can contribute or lead to economic development or growth:

> "A plan is a plan in the true sense of the term only when it is a proposal for action on the part of the one who makes it. The reason our plans for agricultural development have not been plans in the true sense is that they have not been essentially plans for state action. Consequently, many of their targets lack real meaning, validity, and sanction."

More specifically, he states:

> "In all these cases the officers and extension workers know full well that what they can do in achieving these targets is very limited, and that the final decisions lie with the farmers. But they receive orders from

> "above in terms of targets, and they must report their progress in terms of these targets."

After criticising the fact that they are ordering and reporting in terms of items over which the parties concerned have no authority or control, he suggests that agricultural planning, in the real sense of the term, should be confined to those and other areas in which the planner has clear authority to make decisions and initiate action.

This much of the discussion has been on the basic philosophy, nature and purpose of the sector analysis and model. Let us now look at specific kinds of analytical tools or techniques qualified or being used in sector analysis. Adelman and Thorbecke [A.3], Chenery [C.3], and Heady [H.21] present a variety of national, regional and sectorial models built for planning purposes. We will not survey and review all such models here. Instead, we present a typology of agricultural sector models as planning tools advanced by Thorbecke [T.2]:

1. Multilevel planning models
2. Microeconomic-dynamic models
3. Simulation-systems models
4. General equilibrium-consistency models

As examples of the multilevel planning model, he cites Goreux and Manne's Mexico model [G.3] and Vaurs, Condas and Goreux's Ivory Coast model [V.1]. Both are decomposed national models in which the agricultural sector is modeled by the linear programming framework. Many other programming models are used for the agricultural sector planning, and quadratic, multiperiod and reactive programming models have the potential to be used for the same purpose.

The microeconomic-dynamic model is known as recursive linear programming developed by Day [D.3]. Examples include many works by Day-Singh-Mudaha-Ahan.

The system simulation model approach for overall agricultural sector planning seems to have been a domain of the Michigan State University Agricultural Sector Simulation Team [M.4] and [R.7].

The general equilibrium-consistency model seems to include two distinctive models in a sense, according to Thorbecke. One is the econometric model in some respects for Guatemala [F.7], and the other is an informal approach described by Ojala [O.2].

It appears that Thorbecke's typology is unsatisfactory, erroneous and even misleading in many aspects, including his checklist on model classification. First of all, any model he cites except the informal approach model can be, in nature, simulated and built in such a way that consistency criteria can be met. Second, there is no room for the input-output analysis model to play a role in agricultural sector planning. This model may be classified to be included in the programming model. However, the basic philosophy of the model is quite different from the latter, even though the input-output model can be solved by the linear programming solution algorism. He may insist that the general equilibrium-consistency model includes this model, but again, the methodology and data requirements are different from each other.

A good example of using the input-output analysis framework for the agricultural sector planning is found in USAID's Colombia Agricultural Sector Analysis [D.1]. The Colombian agricultural sector model has five components: (1) farms, (2) agricultural marketing entities, (3) processing industries, (4) inputs industries, and (5) service institutions. Each component is again decomposed and analyzed in all 245 subsectors. Another example of the input-output analysis applied is given by Byerlee and Halter [B.18].

Comparisons and contrasts of classes of sector-planning models classified by Thorbecke will not be given here, partially because other ([M.4], [N.3] and [A.2]) have already dealt with this subject and partially because we discussed it briefly earlier. Instead, we will add some brief comments. First, the kind of programming and input-output analysis models built thus far for development planning purposes seem inadequate in at least one aspect. That is, these models assume a linear production function. In other words, a fixed amount of input is required for producing one unit of output. This input requirement is fixed, no matter how the decision encironment is or has been changed. Is this fixed-input requirement assumption realistic in the process of economic development or under the condition of structural change? We have already asked the same type of question on the stability of parameters of econometric models.

We digress slightly to illustrate the problem area. At the annual 1974 meeting of AAEA, several papers dealing with the energy crisis were submitted, which at least two, Penn, et al. [P.3] and Duloy, et al. [D.11] used linear programming or input-output analysis model to study impacts of the energy crisis or fuel scarcity. Several measures have been taken to save oil since the onset of the energy crisis, such as substitution of other fuels, car pools, speed limits, introduction of more small cars, controlling room temperatures, etc. Nevertheless, the models presented above still assume the same technical coefficients as before the energy crisis. This author's question is whether these technical coefficients would be stable and remain the same as before after the crisis, despite the energy-saving measures indicated above. The response of one of the authors was "the stability is one of the model assumptions." But that answer avoids the question that has to do with the reality of the assumption. One should not become a slave of the assumption of a particular technique, instead of being loyal to the real world as much as possible.

According to Falcon [F.1],

> "First, agricultural production is typified by the wide range of input substitutions which are technically possible--not by fixed coefficients. Secondly, one of the primary objectives of an agricultural development program is to change the input-output coefficients associated with agricultural production; therefore to extrapolate inputs or outputs on the basis of historically derived average coefficients for agriculture, as has several times been done, is to violate the basic premise of the entire rural-development program."

There would be absolutely no question as to the fact that technical change introduces new factors into production function, which changes the input-output coefficients for other factors. Nevertheless, one may try to seek an excuse for maintaining this stability assumption with data problem. The able researcher should be able to do what a layman cannot, i.e., to build in a structure to get rid of this unrealistic assumption. Crude components would be much better than complete omission or oversimplification of the important aspect of development and growth. [1]

---

[1] In a class discussion paper, the author [L.9] has demonstrated

This author has more to say about Thorbecke's typology of sector models. Let us ask: are those sector planning models mutually exclusive or substitutable? Can models in his classes I, II and IV adequately handle every problem a sector faces? Mexican and Ivory Coast models are decomposed into many sectors and used several techniques to model. Mudahar's recursive linear programming model [M.27] has a product price generation component. The Korean Agricultural Sector Simulation model embraces a linear programming component as well as an input-output model, and is multilevel as well. How do you interpret all these facts? In sum, what this author is saying is that this classification has less and less meaning as one tries to construct a sector planning model to accurately and realistically model the domain of a problem since I, II and IV intermingle together. Do not become a slave of a particular technique. Instead, be willing and able to honestly incorporate any type of technique wherever it is appropriate for the purpose of constructing a sector planning model, no matter what our disciplinary orientation and prior experiences with specialized techniques are.

Griffin and Enos [G.4, p. 28-29] identify two groups of planners. One group seems to use the sector planning models discussed above. The second group, according to them, starts from the assumption that growth-restraining factors are neither numerous nor equally strong. Accordingly, the planner's task is to concentrate maximum energy on weakening or

---

a methodology so that the input-out coefficients can be time varying, depending on investment made.

breaking a few critical bottlenecks. Therefore, they are more interested in isolating, analyzing and solving specific problems. Most agircultural economic development theories seem to belong to this second group of planners.

As Griffin and Enos point out, which of these approaches is most appropriate to a particular country will depend largely on the circumstances. According to them,

> ". . .the second approach is likely to be more useful (a) the more fragmented is the economy, (b) the less sophisticated is the industrial sector, (c) the larger is the share of foreign trade, (d) the more in need of reform are the major institutions. On the other hand, comprehensiveness and consistency in planning will be more important in economies in which interindustry flows are large, institutions are well adapted to modern needs, and foreign trade is relatively unimportant, i.e. in economies in which the growth impetus originates in the domestic industrial sector."

However, these two planning approaches are not mutually exclusive. Instead, the bottleneck or limited factor approach seems to provic the sector planning approach with good theoretical background and departure of empirical tests.

In summary, we have briefly reviewed quite a diverse body of literature concerning economic growth and development in agriculture, which constitutes the background to the present study. In this study, we try to synthesize relevant theories reviewed here to produce a component for the Korean agricultural sector analysis model for development policy analysis. We have not reviewed many other relevant theories or empirical studies that this study has adapted, such as modified neoclassical economic theories, application of systems science and various techniques. However, these theories and techniques will be reviewed in subsequent chapters or sections.

CHAPTER II

KOREAN AGRICULTURAL SECTOR STUDY (KASS) MODEL

Since the model presented in this report is being developed as a subsector component of the Korean Agricultural Sector Study model, it is desirable to first discuss the KASS model briefly to better understand the present effort. The KASS is related to the following four national value constellations important in Korean agricultural development:

1. Quantitatively and qualitiatively improved food supply.
2. Realization of high-quality of life in rural Korea.
3. Contribution from the agricultural sector to the development of Korea.
4. Administration and political processes affecting Korean agriculture.

Based on these value constellations, the KASS team has developed the major performance variables of the model for evaluating alternative agriculture development strategies as follows:

1. Gross agricultural product
2. Gross nonagricultural product
3. Sector growth rate
4. Nutritional levels in terms of calories and proteins
5. Per capita incomes in each sector
6. Employment levels
7. Tax revenues

8. Trade balances

9. Others

The KASS team has made a number of projections for relevant variables. As we review individual components of the KASS, we will review these projections.

What kinds of input or policy variables are conceived as important for attaining these development goals? The KASS has established major policy variables as follows:

1. Research and extension

2. Land and water development

3. Labor substitution (mechanization)

4. Food price

5. Import policy

6. Other infrastructure investment

7. Family planning program

By what mechanisms or processes do these policy variables influence the performance variables? These policy variables must have some power to change the resource base and/or influence decisions of individual farmers and consumers. That is, these policy variables indirectly influence performance variables by altering farmer decisions and the resource base. How does the KASS model link this set of variables with farmer decisions? To help understand this linkage and interaction among various subsectors, the flow chart of the KASS model is reproduced in Figure 2.1.

The KASS team divides the Korean agricultural sector first in terms of function and space. The functional subsectoralization of

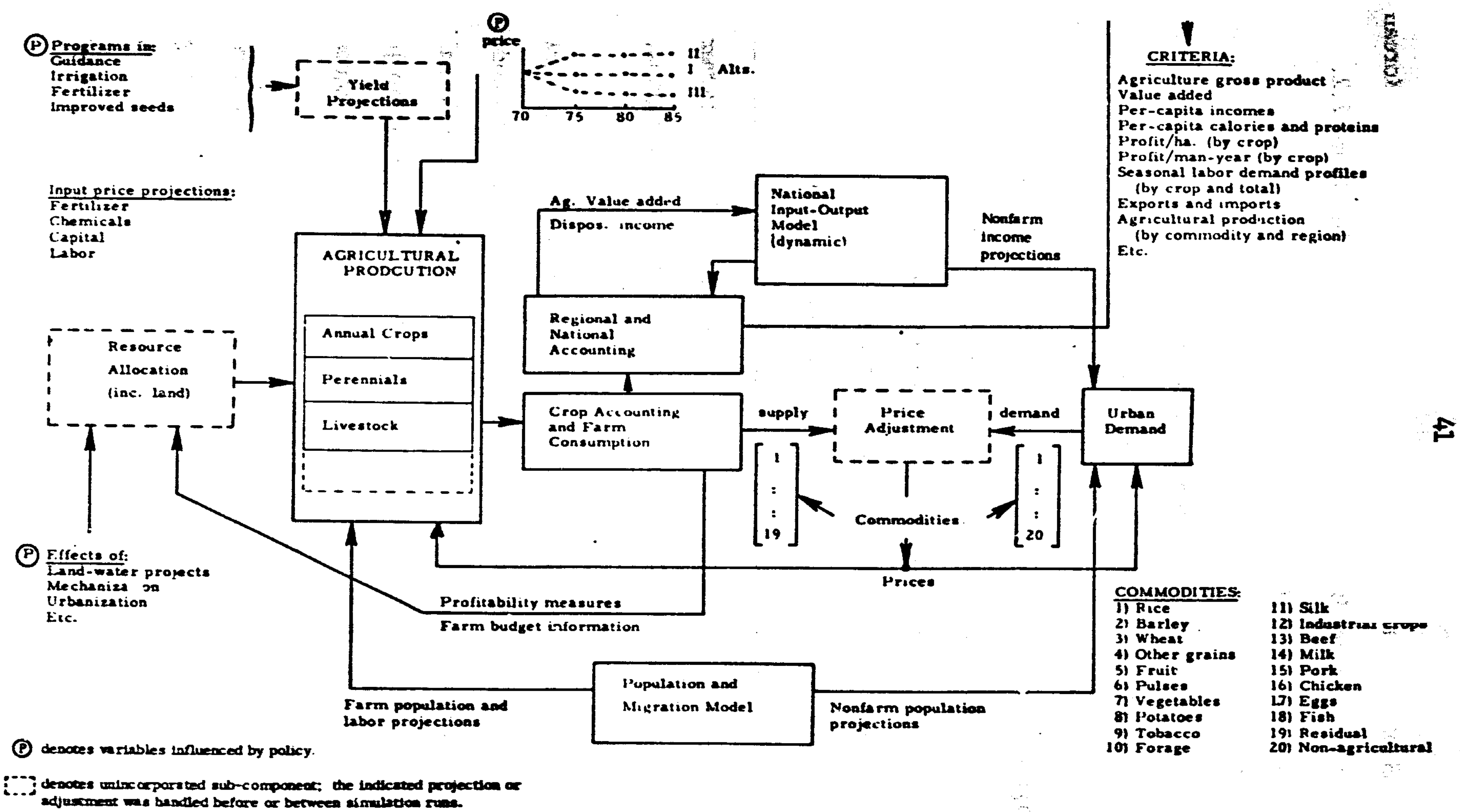

Figure 2.1. Functional flow chart of Korean agricultural sector model.

the KASS model is shown in Figure 2.1. The KASS divides the Korean agricultural sector into three regions, as shown in Figure 2.2. Region 1 includes two northwest provinces where single crop paddy is dominant. Region 2 includes the four southern provinces where double-cropping is dominant, and Region 3 is made up of other agricultural regions where upland cropping is relatively important in production.

There are nine functional subsectors in the KASS model, as seen in Figure 2.1. However, three of them (shown with a dashed outline) were not completed by the time the sector report was published [Rossmiller et al. (R.7)]. Thus the remaining six components were used to make computerized projections for each alternative policy set projection developed by committees for the three informal subsectors. Note that all policy variables except family planning programs, directly or indirectly conceived to affect the resource base and other farmer decision variables. These policy variables induce technological, institutional and human change.

Despite the crucial functional linkage between policy variables and technological, institutional and human changes, the KASS model links these two sets of variables informally. For these informalized subsectors, KASS used what Johnson [J.12] calls traditional projection. Black and Bonnen [B.8] and many others have used these techniques, which are reviewed in a later chapter.

Let us look more closely at each component. Interested readers are urged to refer to the original report. Yield levels of 19 agricultural commodities or commodity groups are projected for 1975, 1980 and 1985 by a committee for each of three regions and for each of

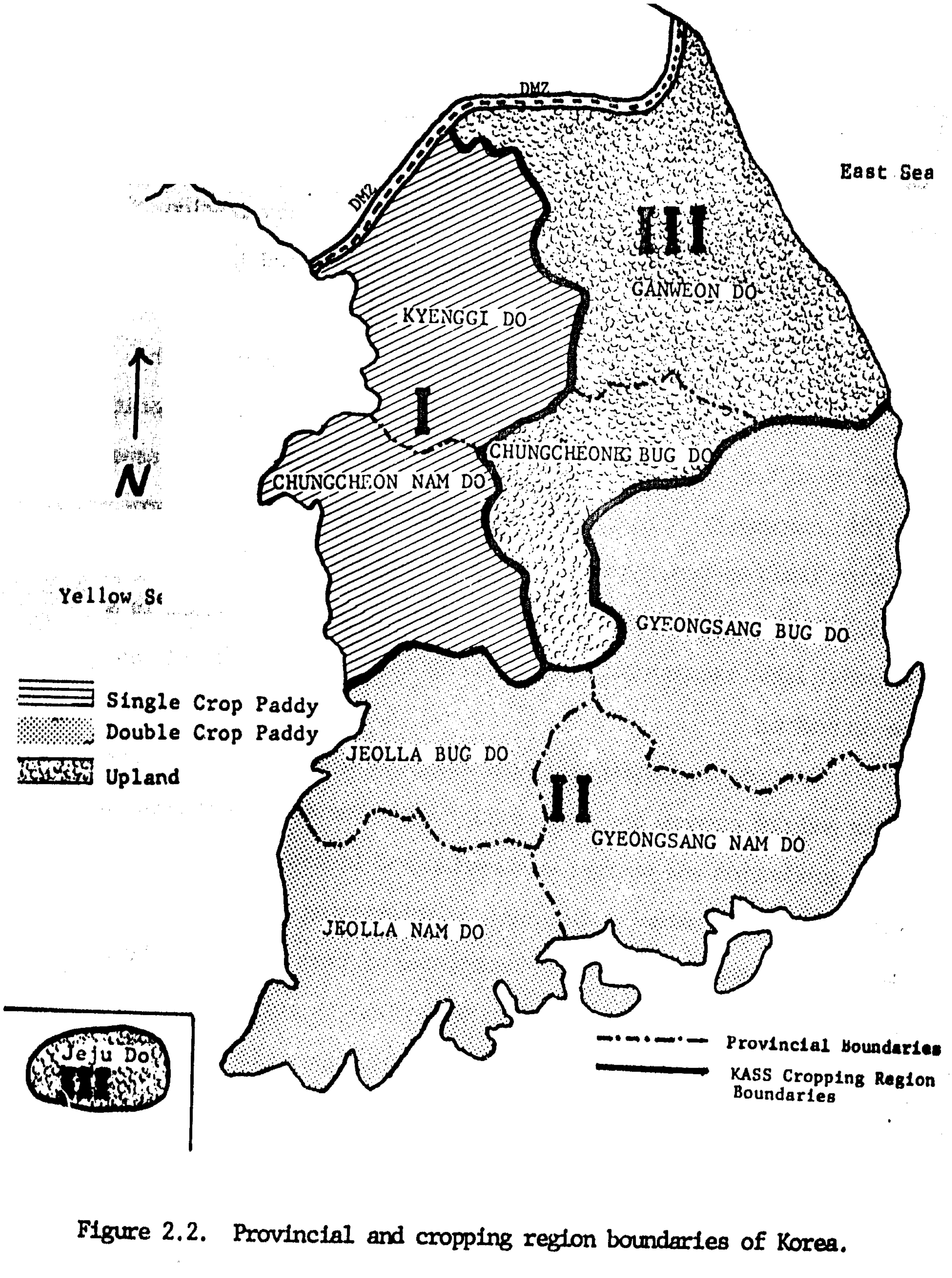

Figure 2.2. Provincial and cropping region boundaries of Korea.

three policy alternatives. Behavioral or formal functional relationships with farmer decision variables were considered by the committee on an ad hoc basis.

The resource allocation component deals mainly with land allocation to each of 12 crops or crop groups, taking into consideration new land development and land disappearance due to urbanization. Land allocated to each crop or crop group was also projected informally, taking price relationships into consideration.

The agricultural production component first determines the physical production level of the agricultural commodity or commodity group by multiplying yield and acreage. There are two dynamic aspects in this component. The first is simulation of perennial crop production (such as tree fruit) by using a subroutine of distributed delay (DELDT), which was developed by Abkin [A.1]. The second is a seasonal labor requirement profile so that mechanization level can be determined.

The crop accounting and farm consumption component determines gross and net revenue and farm consumption. The difference between total production and on-farm consumption and losses at various market stages is called marketed surplus. An interesting feature of this component is change in on-farm inventories of farm products. Such inventory changes in turn influence market supply over the season so seasonal price level can be determined by interaction with urban demand. The regional and national accounting component computes aggregate performance variables such as value added.

The national input-output component, which is represented by a 2 x 2 matrix (one for the farm sector and another for the nonfarm sector) was not actually incorporated into the model for the first phase of the project. Instead projections of nonfarm gross national income and growth rate were made using informal methods. This projection became an input to the urban demand component along with an urban population the size of which was generated from the population and migration component. One interesting aspect of the urban demand component was that income elasticities are time-varying parameters.

As indicated in Figure 2.1, the price adjustment component was not operational by the time the first phase of the project was completed. Instead, the price levels of agricultural commodities other than major grains such as rice were generated by an iterative procedure by accounting supply and demand interaction so that price levels would be stabilized at a reasonable level. Note that the major grain prices are treated as policy variables.

The population and migration component generates many important variables directly related to the farm sector, such as population size by rural and urban, by regions, by sex and age, etc. However, this component is independent from the other components of the model in the sense that there is no interaction between them.

We have briefly reviewed the initial version of the KASS model, which was incomplete as a sector study model. Yield projection, resource allocation, price adjustment, and national input-output model components were treated as exogenous; interaction between farm and nonfarm sectors and among agricultural regions were not taken into consideration; the model is indadequate or is missing several important components such as modern input supply, food processing, and distribution, income distribution, employment, etc., which are extremely important in agricultural development processes.

Fortunately, the KASS is a continuous study. The second phase of the KASS project is concentrating on refining the initial version and building in additional components so that the model is more realistic and capable of planning objectives more precisely. At the present time, there are several ongoing projects dealing with this matter, including a linear programming component to deal with farm resource allocation, the price adjustment component, the government grain management component to deal in part with stabilization of seasonal price fluctuation, the national input-output model component, and refinement of the population and migration model component.

The model presented in this study is also an attempt at refining the initial version of the KASS model, focusing mainly on the functional relationship among crop yields, factors used, and public investment. The model presented here is primarily designed to supply the farm resource allocation component, a recursive linear programming model, with the necessary parameters over the planning horizon (1971 to 1985). Included are yields, factor demand, objective function coefficient components other than prices, and land resource constraints. Thus, we will briefly examine the structure of the farm resource allocation component for better understanding of this effort. The discussion is based on papers by De Haen and Lee [D.7], De Haen [D.6], and Lee [L.10].

The overall flow chart of the KASS model after the farm resource allocation component model is introduced is shown in Figure 2.3. Let us examine the changes. First of all, two components, the resource

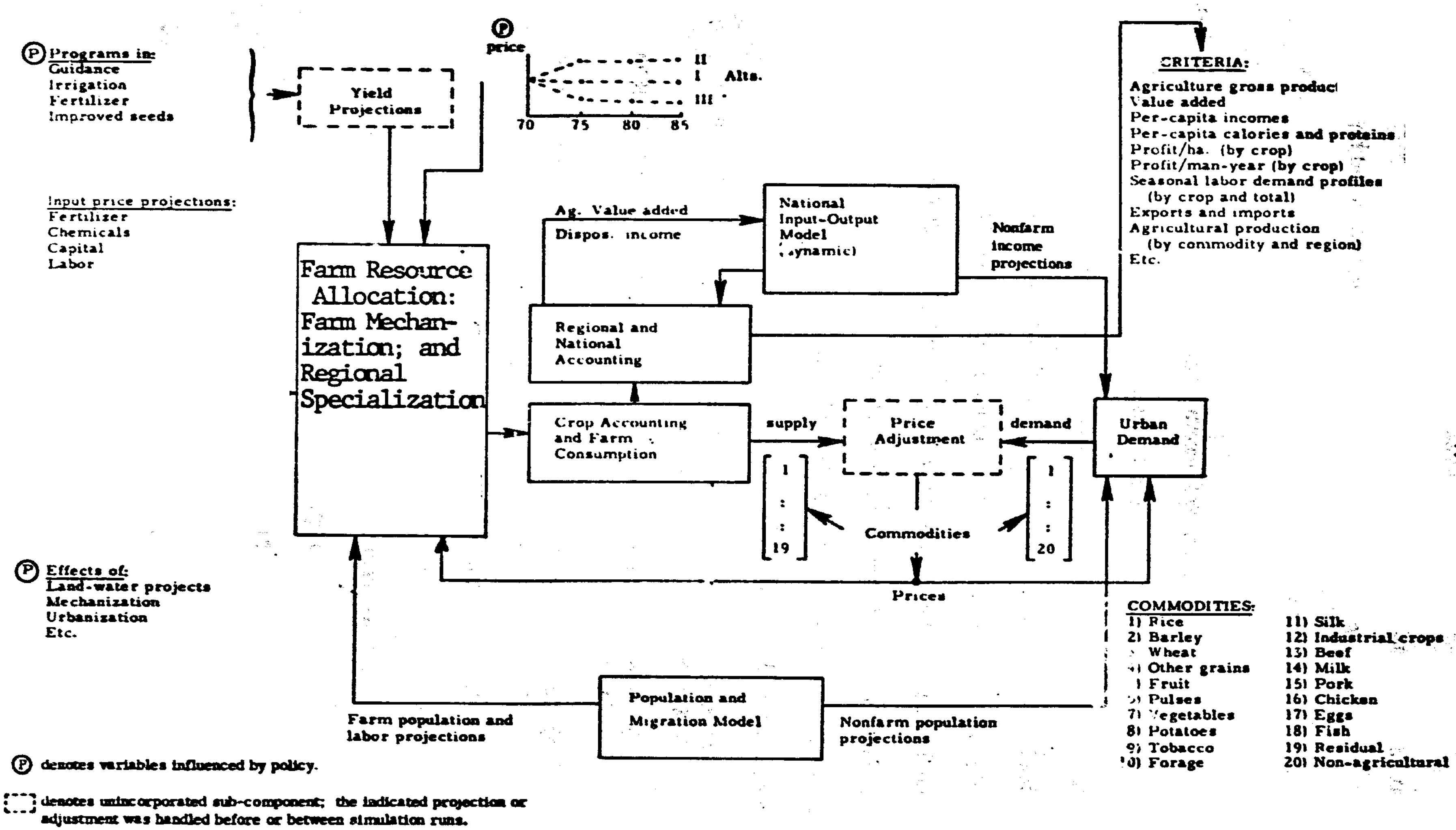

Figure 2.3. Modified functional flow chart of Korean agricultural sector model due to farm resource allocation component addition.

allocation and agricultural production components in Figure 2.1 of the initial version of the KASS model, are now merged together as the farm resource allocation component in Figure 2.3. This new component is designed to deal mainly with allocation of farm resources (land, labor and others dealing with different agricultural production activities). At the same time, the model deals with the level and type of farm mechanization and feed grain imports. A more important aspect of the model, which the initial version of the KASS model ignored, is an economic adjustment of regional production patterns.

The basic inputs to the new linear programming component are yields, price levels of products and inputs, and total land and labor force available. With these inputs, the main outputs of this component can be categorized as follows:

1. Inputs to the crop accounting and farm consumption component:
    a) Areas allocated to each commodity or commodity group for each region in each year.
    b) Production of each livestock commodity group for each region in each year
    c) Total value added
2. Input to other components:
    a) Capital requirement for farm mechanization
    b) Feed grain import
    c) Farm input requirement
    d) Others
3. Inputs to the next iteration of linear programming model itself:
    a) Capital stocks (farm machinery, perennials, large animals, etc.)

b) Shadow prices for some intermediate products

c) Others

In summary, the new programming component does not have its own particular set of policy variables. Instead, it receives policy variables or alternative development strategies directly from the existing simulation model. The programming model then describes how the farm firm translates these policy varialbes, which are revealed in a set of informal projections mentioned earlier, into forms of agricultural production; hence, supply response through resource allocation.

In formal form, the programming model can be stated as follows:

$$2.1 \quad \max \Pi(t) = \bar{V}(t)*\bar{X}(t)$$
$$\text{subject to } \underline{A}(t)*\bar{X}(t) \leq \bar{B}(t)$$
$$\text{and} \qquad \bar{X}(t) \geq 0$$

Where $\Pi(t)$ stands for the value of the objective function, $\bar{V}(t)$ for a vector of objective function coefficients, $\bar{X}$ for a vector of activities, $\underline{A}(t)$ for a matrix of input-output coefficients, and $\bar{B}(t)$ for a vector of constraint capacities, in time period t. The objective function coefficients are computed basically:

$$2.2 \quad \bar{V}(t) = P_{yj}(t)*Y_j(t) - P_{zi}(t)*Z_{ij}(t)$$

Where P_{yj} stands for j^{th} output price, P_{zi} for i^{th} input price, Y_j for j^{th} yield, and Z_{ij} for i^{th} input for j^{th} outputs, in time period t. As already implied, all elements in $\bar{V}(t)$, $\underline{A}(t)$, and $\bar{B}(t)$ are exogenously determined, except some of $\bar{B}(t)$ concerning the flexibility constraints and some of $\bar{V}(t)$.

The kind and type of agricultural production activities are essentially the same as those defined in the intial version of the KASS model and appearing in the footnote of Figure 2.1, with some exceptions: first, after combining other grains with pulses, this commodity group is divided into summer and winter grains. The second change is to add a new activity of forage production from pasture. The third is to divide each crop production activity into two different processes--one with traditional production methods, and another with a package of modern machine inputs, except for rice and pasture management.

Rice, being the most important crop in terms of production as well as consumption, four processes are defined: (1) traditional methods, (2) power tiller, (3) rice transplanter, and (4) power tiller and rice transplanter. The grass production from pasture also has two processes: (i) with fertilizer and (2) without fertilizer. The livestock production activities are the same as those defined in the simulation model, except that a new activity of Korean cattle raising is introduced. The rest of the activities in the programming model are machinery investment, perennial investment, feed import, etc.

There are a variety of constraints. The constraints directly related to the present study are for land and labor. The former is divided into three categories: summer paddy, summer upland and winter land. The latter has two categories: labor that peaks during June and peaking during October. The rest of the constraints are conventional, such as traditional flexibility constraints (Day, Singh, Mudaha, and Ahan [D.3, D.4, M.27 and A.6]).

We have briefly discussed the main features of the farm resource allocation component model. The introduction of this component has considerably improved the resource allocation mechanism of the KASS model in many respects. However, the basic criticism of the initial version of the KASS model is still applicable: its programming model does not contain any economic development and growth theory. In other words, the programming model explains neither how technical, institutional and human changes take place, nor how public investment affects crucial farmer decision variables. In fact, Falcon [F.1] makes an excellent point,

> "Agricultural production is typified by the wide range of input substitutions that are technically possible--not fixed coefficients. . . (and) one of the primary objectives of an agricultural development program is to change the input-output coefficient."

All but a few input coefficients are assumed fixed, and the possibility of factor substitution is very restricted in the farm resource allocation model of KASS.

A programming model can be constructed to simulate the impact of various levels of public policies, programs and projects on the performance of the agricultural sector. A good example is found in the Mexico model [G.3]. The programming model has many strengths, such as power to handle interdependency of economic development (consistency criteria) in addition to handling resource allocation, but it has weaknesses, too. The profit maximization assumption is often criticized [M.4]. In addition, especially with multilevel, multiperiodic or recursive programming, computer capacity is often restrictive for modeling of a large system with nonlinear relationships.

In summary, the major questions this study tries to ask are: (1) how structural change would take place, (2) how this structural change would affect the resource base and/or its productivity, and (3) how the farmer decision is related to this change in resource use, and hence, product supply. More specifically, we intend to explain production response more systematically, depending on public policies, programs and projects.

CHAPTER III

PURPOSES, OBJECTIVES AND SCOPE OF THE STUDY

Purposes of the Study

Now that the basic aspects of Korean Agricultural Sector Study model and its farm resource allocation component have been discussed, the reader is equipped with the minimum knowledge for understanding the basic purpose of the model presented in this study.

One of the most important purposes of this study is to build in a yield projection component for the KASS model. A more crucial purpose is to generate technological, institutional and human changes by means of public policies, programs and projects, and to link these changes to farmer decision variables. The impact of public investment is not directly revealed in the change in yield. Instead, public investment induces changes in the number, quality and quantity of inputs, which we call here technological, institutional and human changes. Hereafter these changes will be called structural change in accordance with Learn and Cochrane [L.3]. Changes affect resource uses, as well.

Our first task is to explain how technological, institutional and human changes occur through public investment. Second, we need to explain how these changes affect resource use, which is factor demand. A change in factor use changes the output level along a given production function, whereas the change agency discussed above shifts among sub-production functions. As implied above and discussed in a later chapter, it is theoretically perfectly possible for factor demand and product supply (yield) projections under the structural change to be made from a linear programming framework by a series of linear approximations. However, the approach is avoided here for reasons to be pointed out later. This study develops an alternative approach, the development of which is another basic purpose of this study.

Each researcher in every specialized disciplinary seems to believe that his own techniques are dominantly realistic and capable of explaining the real world and criticizes other approaches while tending to hide the weakness of his own approach. We should be able to respect the strength of other disciplines and techniques while recognizing the weakness of our own. In other words, any technique and theory from other schools should be used whenever and wherever they are appropriate and more realistic.

The purpose of a sector analysis should not be a simple application of a particular disciplinary theory or technique, but to reasonably and accurately model a sector's behavior to provide sufficient information for planning with respect to the problem of the sector. Thus, an important purpose of this study is to illustrate how two or more different disciplinary approaches can be incorporated or merged together by feeding in as well as feeding back.

From the above discussion, it is easy to identify the system we want to model. The major inputs to the system can be classified as follows:

1. Public investment by central and local government in the form of finance or subsidies.

2. Price policies for products as well as inputs.

3. Credit policies with respect to amount and rate of interest.

The major system outputs under consideration for each region are:

1. Yield levels by agricultural commodities under consideration.

2. Input levels and variable costs by commodities.

3. Labor demand by commodities and season.

4. Available land by categories.

These variables will be fed directly into the farm resource allocation component of the KASS model. The development economist might be interested in other outputs too. Off-farm income and employment generated indirectly or directly by public investment are good examples. Seasonal rural employment level can easily be estimated, once land allocation is determined by the farm resource allocation component model. The same is true for some aspects of income distribution.

Another category of variables, which relates output to input variables is called state variables. The various types of improved land, land that has adopted a new technology, etc., belong to this class of variables. The output variables described above are also a type of state variable in this particular case. The final outputs of total system in the context of the Korean agricultural sector are called performance variables as mentioned earlier. The system we want to model can be expressed as follows:

$$3.1 \quad \frac{d\bar{X}(t)}{dt} = \underline{A}\bar{X}(t) + \underline{B}(t)\bar{U}(t)$$

Where $\bar{X}$ stands for a vector of state variables, $\bar{U}$ for a vector of inputs, and $\underline{A}$ and $\underline{B}$ are, respectively, a matrix of parameter set.

Now let us be more specific about the kind of policy inputs, so the scope of the study and its objectives can be understood more clearly. The public policies, programs and projects under consideration are classified as follows:

1. Public Investment Programs
   a. Biological research
   b. Extension
   c. Tideland development
   e. Upland development
   f. Large-scale paddy irrigation
   g. Small-scale paddy irrigation
   h. Paddy land consolidation
   i. Paddy land drainage
   j. Upland consolidation
   k. Upland irrigation
2. Public Policies
   a. Price policies
      i. Product price policy
      ii. Input price policy
   b. Credit Programs
      i. Credit available to the farm sector
      ii. Interest rate policy.

There are many other public policies, programs and projects that affect agricultural development and rural development or welfare. Mosher [M.25], among others, advocates the integrated development strategy. Transportation, marketing facilities, electrification and other infrastructure would be equally important variables that can provide producer with incentives. The same thing is true for public programs for the agribusiness sectors, such as modern input production and agricultural processing. The public programs in these sectors are not considered in this study, partly to keep the model at a manageable size, partly because production functions of these infrastructures are not clearly known, and partly because there is a possibility of designing another KASS component to deal with some of these public programs. The agricultural input supply function is still assumed horizontal, but public programs can influence the price level by various measures.

Let us again summarize what this study intends to do and its basic idea by a means of flow chart. A modified version of Korean Agricultural Sector Simulation model after the addition of the component model presented in this study is shown in Figure 3.1. The right side of the figure is exactly the same as that shown in Figure 2.1.

In this system, there are two decision boxes represented by a diamond in the figure. One is for allocation of public investment, and the other for public policies such as price subsidies and credit programs. As seen in the figure, it is believed that the public investment induces technological change, referred to here as structural change. Note that structural change is not induced by change in the relative price, but is generated by the public investment. Also, the public investment does not directly affect production level or resource use, but affects them indirectly through a change in input quality or quantity, material or immaterial, or in incentive. Land and water development, biological research and innovation diffusion represent

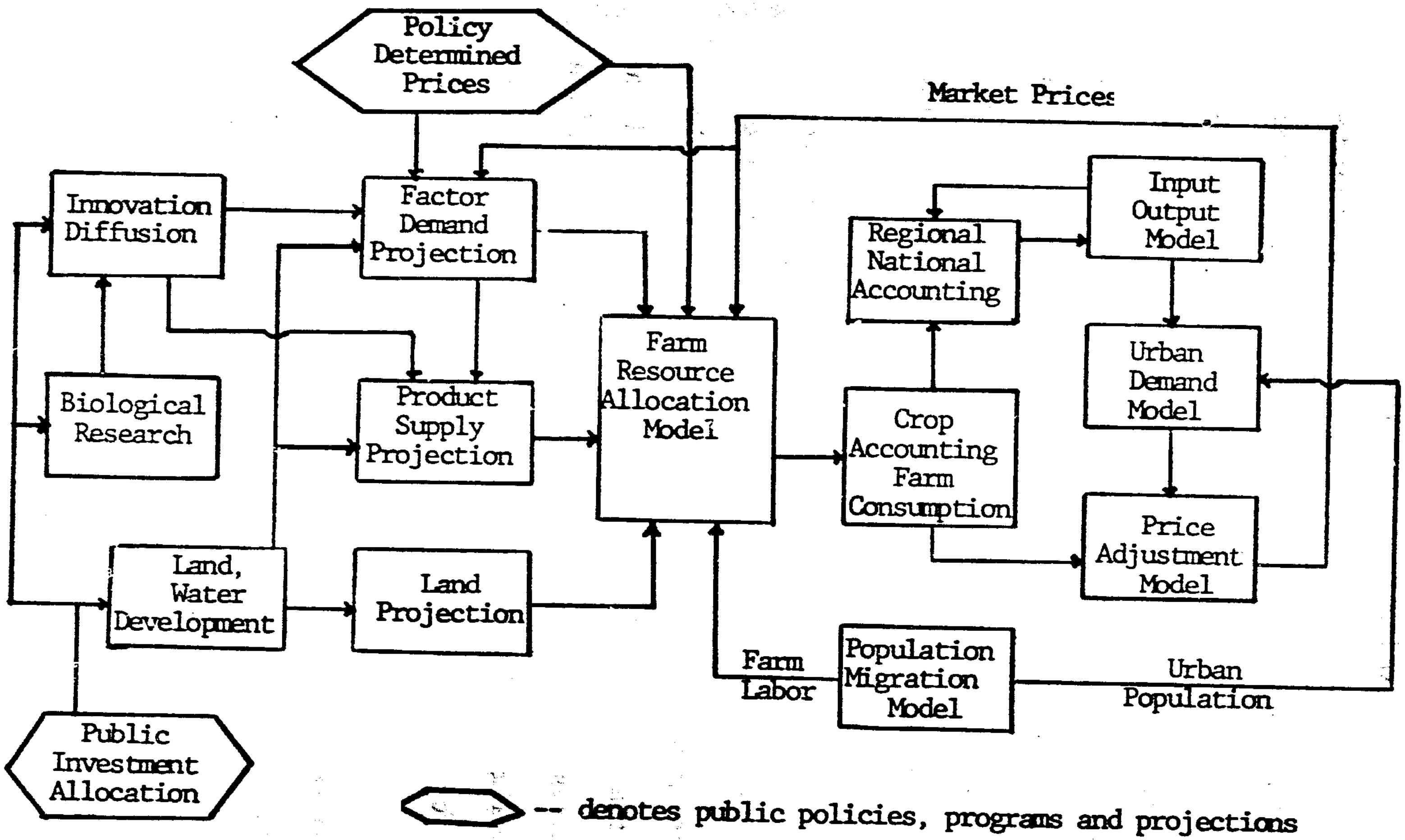

Figure 3.1. A modified version of Korean Agricultural Sector model.

the change in inputs in quality or quantity in Figure 3.1. The first two components are represented as a function of public investment alone, but innovation diffusion is represented as a function of public investment and outcomes of biological research, among others.

Various land categories are direct outcomes of land and water development, and can be fed directly into the resource constraint of the farm resource allocation component. Hereafter the three subcomponents discussed above will be referred to as the public investment sector component. There is another subcomponent, which will be called the farm micro production component. This includes the factor demand and product supply subcomponents of Figure 3.1.

Note that public policies can now have a role in agricultural production--they can directly affect resource use. Thus, product supply can be influenced by public policies that influence resource use. Resource use is also influenced by structural changes discussed above. Once resource use and structural changes that shift subproduction function are determined, product supply can be computed as shown in Figure 3.1, since product supply is an exclusive consequence of resource use. Both subcomponents of factor demand and product supply in Figure 3.1 supply the farm resource allocation component with input-output coefficients, as well as the physical components of the objective function of the farm resource allocation component.

Scope of the Study

Thus far, the discussion has indicated what will be done, now we will mention what will not be dealt with in this study.

First of all, no particular mention will be given to income distribution and other measurements of economic and rural development or quality of rural life. These aspects are ruled out simply to keep the model manageable, and particularly because the KASS model already deals with some of the variables.

Projections of product supply and factor demand have little meaning until projections are used to estimate higher-order performance variables, such as total production, value added, etc., for examining the degree of attainment of development goals. For this alone, this study should be extended to feed in projections made into the farm resource allocation component model. The combined projections should also be linked with the existing KASS simulation model. This is desirable to capture the dynamic interactions among components and for evaluating policy alternatives in terms of performance variables. The KASS simulation model is a product of multidisciplinary team work. Since its components are disaggregated, it seems that aggregation of components requires similar mutual incorporation. All this implies that it is almost impossible to put all components together right after one new component is developed, especially in view of the inflexible time constraint faced by the author.

As mentioned earlier, one of the objectives in building the farm resource allocation component was to deal with farm mechanization. Farm machinery is one type of farm input. The machinery service demand for individual crop production is of exactly the same nature as demand for other inputs. Even if machinery investment could be determined by the programming model, allocation of the service from the existing stock of machinery could be determined more logically and precisely by the initial version of the model presented in this study. However, there is some inconsistency of allocation of variables among components. The subcomponent model presented in this study does not include projection of machinery service demand for individual crops.

In turn, this creates one more restriction. That is, the machinery input under consideration in the KASS model is purely labor substitute. There are many economic and agronomic studies indicating that farm mechanization has a yield-increasing effect, but no study provides a positive answer.[1] In other words, labor demand cannot be determined independently of demand for machinery, and vice versa. Thus, it was decided to project the labor demand for the so-called traditional processes of individual crop production defined in the programming model, then the labor saved due to mechanization will be subtracted from the labor demand for traditional process in order to project the labor demand for the mechanization process. Thus, a few equations written in FORTRAN computer language would have saved at least one-third of the activities defined in the programming model, which is a big advantage, especially as a computer capacity is a restrictive factor.

On the other hand, the KASS model contains five livestock, one fishery, and residual production activities, in addition to 12 crops. The programming model component deals with crop and livestock activities, not with the last two activities. It would be more logical if the model presented in this study generated input-output coefficients

---

[1]Former Director of Crop Experiment Station, Dr. Young Chel Chang, highlighted the doctrine of heavy fertilization and deep plowing for several years, but was unsuccessful.

for all activities defined in the KASS model over time as functions of policy variables. Reference to the field of activities excluded here seems extremely scarce. Furthermore, the scope of the present study has already turned out to be considerably large in the light of the time allowed. Thus, the model for livestock input-output relationship has been postponed until a later date.

Objectives of the Study

We are now ready to specify the objectives of this study in detail. We will develop a systems simulation component model based on neoclassical economics, including development as well as growth theories. The main purposes of this model are: (1) to link public decisions with change in the agricultural resource base in terms of quality and quantity, (2) to relate these structural changes to farmer decision variables, and (3) to supply the farm resource allocation component model with necessary parameters subject to the dynamics of changing development policies, as seen earlier. All these subcomponents constitute the production side of the KASS model. As noticed earlier, this production side will be linked with the rest of the model. The crucial variables affecting the performance of the agricultural sector are public policies, programs and projects, represented by diamonds in Figure 3.1. The KASS team initially examined three sets of policy alternatives in terms of these policy variables. These sets are summarized in Table 3.1.

Policy alternative set 1 corresponds to the third five-year plan (1972-1976). According to Rossmiller, et al. [R.7], the major policy goals for agriculture include the following:

Table 3.1. Summary of Policy Components of Alternatives II and III Relative to Alternative I.

Policy Component	Emphasis or Position Relative to Alternative I	
	Alternative II	Alternative III
Research and guidance programs	More	Same
Land and water development	Same	Less
Labor substitutes	As Needed	As Needed
Food prices	Higher	Lower
Import policies	Same	Open
Import policies	Same	Open
Infrastructure	More	Less
Family planning program	More	More

Source: Rossmiller, et al. [R.7, p. 65].

1. Increasing the production of agricultural products, with emphasis on attaining full self-sufficiency in food grains, particularly rice, by 1976.
2. Increasing incomes for farmers, with emphasis on narrowing the farm-nonfarm income gap.
3. Improving the quality of rural life, with emphasis on infrastructure and public service development.

The major policy instruments for attaining these policy goals are stated as follows:

1. Establishing an expanded agricultural production base.
2. Improving agricultural research and extension efforts.
3. Improving the market system.
4. Encouraging the export of agricultural products.

The model presented in this study will examine or deal with the following policy question more specifically:

1. What would be the impact on product supply and factor demand over the planning horizon of 15 years (1971-1985) of:
   a. Alternative land and water development policy?
   b. Alternative biological research and diffusion of its results?
   c. Alternative product and input price policies?
   d. Alternative credit programs?
2. What would the dynamic interaction of these individual policies be?
3. What would the impact of these policies, individually or in a package, on a set of performance variables be?
4. What would the optimal strategies of agricultural development for attaining developmental goals be?

PART II

MATHEMATICAL STRUCTURE OF MODEL

CHAPTER IV

PUBLIC INVESTMENT--LAND AND WATER DEVELOPMENT

Introduction

In this part, we present structural equations of the model. The model of public investments for land and water development is constructed in Chapter IV. Chapter V discusses models that use biological research and diffusion for its results. In Chapter VI, a production function that receives the output variables of the public investment subcomponents as production function shifters is presented. The production functions used distinguish between annual crops and perennial crops. From this production function, a product supply projection model is derived. Finally, Chapter VII derives a factor demand equation that receives the output variables of the public investment subcomponents as demand function shifters.

More than 350 variables or parameters and about 300 equations or relationships are defined in this model. Presentation of every technical detail would confuse the reader and might obscure the essential feature of the model. For this reason, in addition to space limitations, only the basic essential structure will be given. Technically minded readers or those who are interested in technical details are urged to refer to the computer program written in FORTRAN in Appendix A.

The variable names appearing in this section are the same as those in the computer program unless otherwise indicated. Subscripts are different, however. This method was designed to help the reader who does not know the FORTRAN language clearly understand the model structure. On the other hand, whenever a certain subroutine already made available to users is used, the corresponding call programming is presented in the FORTRAN language, along with the counterpart of an analytical equation.

Lastly, it is appropriate to describe the composition of the computer program. There are five subroutines constructed for making the necessary projections; PUBINV, SOCDLF, FDYLD, TEMP and IMPMFP (see below). In addition, two subroutines readily available to users are also utilized: DELDD, which is essentially a modified DELDT and DELLVF. Several functions are also used: TABLLE, RANF and AMOD wherever appropriate. All this is written in FORTRAN.

The computer program corresponding to the land and water development subcomponent is shown in subroutine PUBINV. That corresponding to the research and extension subcomponent is covered in subroutine SOCIDF. For technical reasons, the factor demand and product supply subcomponents are put together in subroutine FDYLD. These three are the main subroutines essential for the model presented in this study. However, there are a number of variables that are endogenous in the total system of the KASS model at the present state of development or at least in the near future, but are treated as exogenous in this model. Examples are land areas used to produce each commodity, product prices and so on. At the same time, there are a number of other variables used for more than one subcomponent, such as distributed lag prices, long-run profitability, etc. All variables of this sort are computed in subroutine TEMP. All necessary initial conditions are shown in subroutine INPMFP. Other subroutines or functions will be explained in the text.

In this chapter, we will construct a model of the land and water development subcomponent. The model first relates the change in quantity as well as quality of land with public investment, in a form that allows structural change in the resource base to be simulated over time.

The type of land and water development under consideration in this study was described in Part I. The technique of analyzing this type of investment has traditionally been the ad hoc type of the benefit-cost analysis. There are a number of examples of this approach. It is well known, however, that this approach is inadequate as a sector analysis tool. This author has demonstrated that the benfit-cost analysis technique can be much improved when a system simulation approach is incorporated [L.11].[1] In other words, net present worth, internal rate of returns and the benefit-cost ratio can be more realistically and accurately derived from the model presented in this study, though no attempt is made to do so here.

In principle, this type of investment can be analyzed in a framework of programming model, as mentioned earlier. The trouble is that for the model to be more realistic and accurate, the matrix

---

[1] In this paper, the major components of the social benefit and cost are modeled by difference equations with exogeneous policy variables in order to analyze the impact of establishing a credit union for El Salvador.

size must increase. We seem to have digressed somehow from the main subject matter. At any rate, to seize precisely the indirect effects--induced and stemmed--as well as the direct effects of an investment project,[2] the model should be able to mathematically trace out over time all important interacting variables. For this reason, a more comprehensive and consistent model is constructed for analyzing an investment project.

Let us discuss how to compute the accumulated land improved by means of public investments. That is:

$$4.1 \quad TL_{ik}(t) = TL_{ik}(o) + \int_o^t DSC_i(t)\, dt$$

$$i = 1,2,3 \qquad k = 1,2,\ldots,8$$

Where TL_{ik} represents accumulated improved land of k^{th} land and water development project in region i, and DSC_{ik} represents land area improved in each year by k^{th} project in region i. Land area improved in each year, DSC, which is often called the delay output, is determined by several factors. Implementation certainly involves time lag. With a given time lag or delay, DSC for each year is determined by the rate at which land eneters implementation process. In a simple case DSC can be defined as follows:

$$4.2 \quad DSC_{ik}(t) = E_{ik}(t-\tau)$$

---

[2]Gittinger, in his book [G.1], recommends that the secondary effects such as "induced" and "stemmed" can be disregarded without a significant loss for analyzing an agricultural project. The result based on this methodological suggestion brings about a lower priority of agricultural investment as contrasted to what the real situation would be, resulting in a biased information for policy-makers.

Where E_{ik} equals the rate at which land enters implementation process for project k and in region i, and τ equals the necessary time lag between starting and completing project implementation. For an individual project, this formation would be all right. Since we are dealing with an aggregate model, one sort of project can be taking place in many places at the same time. This implies that the time lag on completing a project varies among different locations.

The delay output rate such as DSC of the project implementation is assumed to be randomly distributed with a specific density function such as the Erland family of probability density function. In other words, the process of the aggregate project implementation can be modeled by a distributed lag model. The appropriate differential equation is:

$$4.3 \quad \left(\frac{D}{K}\right)^k \frac{d^kY(t)}{dt^k} + K\left(\frac{D}{K}\right)^{k-1} \frac{d^{k-1}Y(t)}{dt^{k-1}} \quad t \;.\;.$$

$$+ K\left(\frac{D}{K}\right) \frac{dY(t)}{dt} + Y(t) = X(t).$$

Where:

D = average expected time lag,

K = order of differential equation,

Y = output such as DSC discussed above, and

X = input such as E discussed above.

Two parameters govern the shape of output distribution with a certain input signal: D and K. With a given average expected delay (D), the shape of distribution is determined by K. When K = 1, the shape is exactly the same as exponential distribution. That is:

$$4.4 \quad D\frac{dy(t)}{dt} + Y(t) = X(t)$$

Which is a first-order differential equation. As k increases, the shape approaches that of the normal distribution, but when k approaches infinity, the standard error of distribution approaches zero, which is a discrete delay. Discrete delay is a special case of a distributed dealy.

There are a variety of numerical solution methods for Equation 4.3 to meet different needs using this type of formulation [Manetsch and Park (M.6), and Llewellyn (L.19)]. The particular computerized numerical method used here is called DELLVF subroutine, developed by the Computer Library on Agricultural Systems Simulation [C.7]. There are three reasons for this selection. This subroutine automatically computes the time fraction necessary to secure stability of time solution of differential equations, called IDT, deals with a case of time-varying average expected delay of the project implementation and directly computes land area under process of project implementation. The calling statement to this subroutine in FORTRAN is:

4.5 CALL DELLVF [E(I,K), DSC(I,K), RINT (1,I,K), STRGP, PLRP(I,K) DEL(I,K), DELDP(I,K), DT, KDEL(I,K)]

where:

E = rate of land entering implementation process,

DSC = rate of land leaving implementation process,

RINT = intermediate rate under processing for each stage of KDEL order,

STRGP = sum of RINT that is total amount being processed,

PLRP = losses during processing,

DEL = current time delay,

DELDP = lagged time delay,

DT = time augument for computation, and

DKEL = order of differential equation.

Specific purpose for choosing this particular subroutine will be explained later.

Total land area under the project implementation which is often called storage, can be computed with the simple first-order differential equation:

$$4.6 \quad STRGP_{ik}(t) = STRGP_{ik}(o) + \int_{o}^{t} [E_{ik}(t) - DSC_{ik}(t)]\, dt$$

The computer program corresponding to this equation by Euler's numerical solution method is:

$$4.7 \quad STRGP_{ik}(t+1) = STRGP_{ik}(t) + DT* [E_{ik}(t) - DSC_{ik}(t)]$$

However, we did not use this formulation here since the subroutine DELLVF computes this storage directly. But we did check the convergency of this storage by both computing methods (Equations 4.5 and 4.7).

Once the area of improved land by each category of land and water development in each year, DSC, is determined, the change in each land class can be easily computed using the first-order differential equation. Before presenting the model, we specify several underlying assumptions:

1. Agricultural land can be classified based on a variety of criteria or purpose. The simple scheme adopted serves the purpose of this study. For each region:

A. Paddy land, $TPLAND_i(t)$

1. Permanently irrigated paddy, $PIT1_i(t)$
2. Semi-permanently irrigated paddy, $PIT2_i(t)$
3. Temporary irrigated paddy $PIT3_i(t)$
4. Rainfed paddy, $PIT4_i(t)$
5. Consolidated paddy, $CSLP_i(t)$
6. Drained paddy, $DRDP_i(t)$

B. Upland, $TULAND_i(t)$

1. Consolidated upland, $CSUL_i(t)$
2. Unconsolidated upland, $UCSUL_i(t)$
3. Irrigated upland, $ULIG_i(t)$

Each irrigation type of paddy could be classified by consolidation type and further by drainage type. The number of paddy type would then be 16 which would make the model unnecessarily complicated. Unconsolidated and undrained paddy are missing in this classification because they can be computed directly by subtracting improved ones from total paddy, which is computed as the sum of the four irrigation types. Likewise, we need one type of unimproved upland to compute total upland; unconsolidated upland has been chosen arbitrarily.

2. It is assumed that a certain amount of agricultural land in each region and year will be transferred to urban uses (highway, industrial, urban residential sites, etc.) and termed $TR_i(t)$. It is also assumed that the fraction of each category of land classified above that transfers to urban uses is

proportional to the area of each category and these fraction are termed PLR_i, $i = 1,9$. At the same time, the parameter WIR_i, where $i = 1,9$, is designated to control land retirement for each category if necessary.

3. Each land and water development project can be implemented independently. To simplify the model, it is assumed that the large-scale irrigation project would be multipurpose, performing land consolidation and drainage, if desired, in addition to irrigation. It is also assumed that consolidation and drainage are proportional to the unimproved land in a large-scale irrigation project.
4. The small-scale irrigation project defined here auguments only the area under semi-perfectly irrigated paddy.
5. Paddy consolidation or drainage can be performed on any type of irrigated paddy. The proportion of each type of irrigated paddy consolidated or drained is assumed to be proportional to area of each type of irrigated paddy land.
6. Still another type of irrigation that transforms the rainfed paddy into the temporary irrigated paddy is not considered in this study, since this may not require any form of public investment.
7. For irrigation and consolidation, a certain fraction of land is required for inserting some structure such as an irrigation ditch, path, etc. That is, area available for cultivation is reduced due to these land improvements. This fraction is represented by $PADSC_i$.

8. Tideland development auguments paddy that is perfectly irrigated, consolidated and drained, and upland development auguments only unirrigated and unconsolidated upland.

With these assumptions, the time path of each land class defined above can be described by means of the first-order differential equation. That is, remembering that k index goes 1 to 8 and corresponds to:

k	Project
1	Tideland development
2	Upland development
3	Large-scale irrigation project
4	Small-scale irrigation project
5	Paddy consolidation project
6	Paddy drainage project
7	Upland consolidation project
8	Upland irrigation project

1. Permanently irrigated paddy, namely the paddy in "irrigation associations" as reported in the official publications, $PIT1_i(t)$:

$$4.6 \quad PIT1_i(t) = PIT1_i(o) + \int_o^t [(DSC_{i3}(t) * (1.0 - PADSC1) + DSC_{i1}(t) - PADSC3 * PITP1_i(t) * DSC_{i5}(t) - WTR1 * PLR1_i(t) * TR_i(t)]\, dt$$

2. Semi-permanently irrigated paddy, which is called irrigated paddy in the official publications, $PIT2_i(t)$:

$$4.7 \quad PIT2_i(t) = PIT2_i(o) + \int_o^t [(DSC_{i4}(t) * (1.0 - PADSC2) - PT21_i * DSC_{i3}(t) - PADSC3 * PITP2_i(t) * DSC_{i5}(t) - WTR2 * PLR2_i(t) * TR_i(t)]\, dt$$

3. Temporary irrigated paddy, $PIT3_i(t)$:

$$4.8 \quad PIT3_i(t) = PIT3_i(o) - \int_o^t [PT31_i * DSC_{13}(t) + PT32_i * DSC_{14}(t) + PADSC3 * PITP3_i(t) * DSC_{15}(t) + WTR3 * PLR3_i(t) * TR_i(t)]\, dt$$

4. Rain-fed paddy, $PIT4_i(t)$

$$4.9 \quad PIT4_i(t) = PIT4_i(o) - \int_o^t [PT41 * DSC_{13}(t) + PT42_i * DSC_{14}(t) + PADSC3 * PITP4_i(t) * DSC_{15}(t) + WTR4 * PLR4_i(t) * TR_i(t)]\, dt$$

5. Consolidated paddy: $CSLP_i(t)$:

$$4.10 \quad CSLP_i(t) = CSLP_i(o) + \int_o^t [DSC_{15}(t) * (1.0 - PADSC3) + DSC_{13}(t) * (1.0 - PADSC1) * (1.0 - RCP_i(t)) + DSC_{11}(t) - WTR5 * PLR5_i(t) * TR_i(t)]\, dt$$

6. Drained paddy, $DRDP_i(t)$:

$$4.11 \quad DRDP_i(t) = DRDP_i(o) + \int_o^t [DSC_{16}(t) + DSC_{13}(t) * (1.0 - RDP_i(t) * (1.0 - PADSC1) + DSC_{11}(t) - WTR6 * PLR6_i(t) * TR_i(t)]\, dt$$

7. Consolidated upland, $CSUL_i(t)$:

$$4.12 \quad CSUL_i(t) = CSUL_i(o) + \int_o^t [DSC_{17}(t) * (1.0 - PADSC4) - WTR7 * PLR7_i(t) * TR_i(t)]\, dt$$

8. Unconsolidated upland, $UCSUL_i(t)$:

$$4.13 \quad UCSUL_i(t) = UCSUL_i(o) \int_o^t [DSC_{17}(t) - DSC_{12}(t) + WTR8 * PLR8_i(t) * TR_i(t)]\, dt$$

9. **Irrigated upland, $ULIG_i(t)$**

$$4.14 \quad ULIG_i(t) = ULIG_i(o) + \int_0^t [DSC_{i8}(t) * (1.0 - PADSC5) - WTR9 * PLR9_i * TR_i(t)]\, dt$$

Where:

$PADSC_j$, $j = 1,5$ = land losses due to project,

WTR_j $j = 1,9$ = control variable to restrict the conversion of a certain type of land into urban uses,

$TR_i(t)$ = total land transfer to urban uses in each region which is an exogenous variable to the model,

$DSC_{ik}(t)$ = the rate of land implemented in each year for each of land and water development projects, as we defined before.

Other variables are defined as follows. The purpose or reason for having these variables are explained briefly above. $PITP_{ij}(t)$ is the proportion of each irrigation type paddy to total paddy, that is:

$$4.15 \quad PITP_{ij}(t) = PIT_{ij}(t)/TPLAND_i(t)$$

Where $PIT_{ij}(t)$, $j = 1,4$, is paddy area by irrigation type defined above, and $TPLAND_i(t)$ is total paddy in each region. $PLR_{ij}(t)$, $j = 1,9$, is proportion of each land category defined in Equations 4.6 - 4.14 to total in each region, and total land TLAND, is defined as the sum of paddy and upland in each region.

In principle, the less perfectly irrigated paddy can be transformed into any type of more perfectly irrigated paddy. For example, it is not necessary for the temporary irrigated paddy to be transformed into a semi-perfectly irrigated paddy first in order to be transformed into a perfectly irrigated paddy. A large-scale irrigation project usually transforms some of each type of less perfectly irrigated paddy into perfectly irrigated paddy. Parameters, $PT21_i$, $PT31_i PT32_i$, $PT41_i$ and $PT42_i$ specify the proportion of each of the less perfectly irrigathed paddies transformed into a more perfectly irrigated paddy. For example, $PT32_i$ is the proportion of irrigation type 3 transformed into irrigation type 2, so that the following relationships hold:

4.16 $$PT21_i + PT31_i + PT41_i = 1.0$$

4.17 $$PT32_i + PT42_i = 1.0$$

In the above discussion, we did not specify the rate of land entering the improvement process, $E_{ik}(t)$, and assumed this variable was given. This is the variable government has the power to allocate the public budget to various segments of policies, projects and programs. This variable is the true policy variable and is exclusively determined by two factors: total budget allocated to each project in each region and unit cost of each project.

Let us discuss the unit costs necessary to implement each project. Can we assume without loss that this unit cost is constant over time, no matter how much land is transformed? There are reasons that unit cost would be an increasing function of time as low-cost projects will be implemented first. It is assumed here that the unit cost curve is an increasing function of total land improvement for each land and water development project, as shown in Figure 4.1. Here the independent variable could be either improved accumulated area or accumulated area entering the improvement process. For the purpose of computing the required budget, we concluded this independent variable to be a simple average of unit costs computed both ways. That is, the unit cost for each project, $APSC_{ik}(t)$ is now:

$$4.18 \quad APSC_{ik}(t) = [APS1_{ik}(t) + APS2_{ik}(t)]/2$$

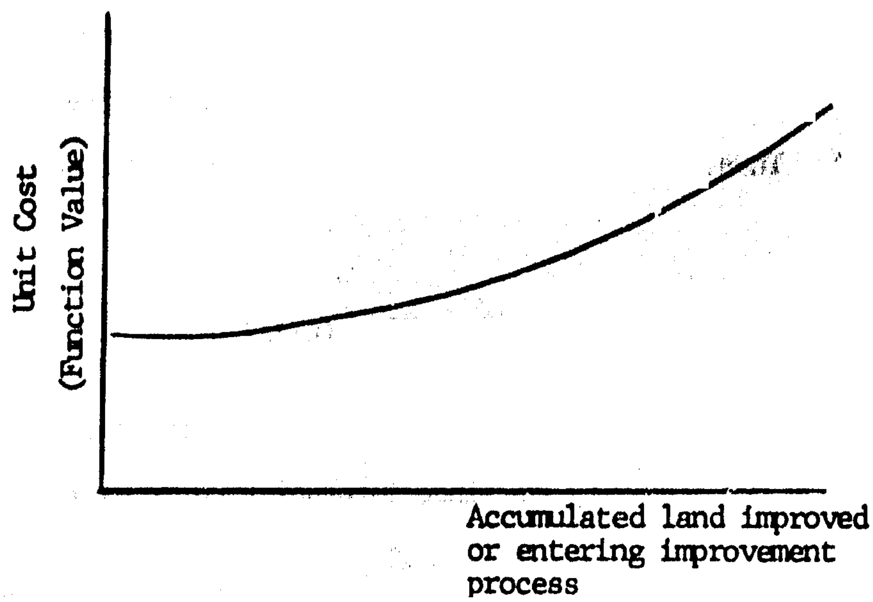

Figure 4.1. Relationship between unit cost and accumulated land improved or entering improvement process for each project.

Where:

$APS1_{ik}$ = unit cost computed from Figure 4.1, based on accumulated land entering the improvement process,

$APS2_{ik}$ = unit cost computed from Figure 4.1 based on accumulated land improved.

The accumulated lard entering the improvement process can be computed:

$$4.19 \quad S_{ik}(t) = S_{ik}(o) + \int_o^t E_{ik}(t)\, dt$$

Where:

$S_{ik}(t)$ = accumulated land entering improvement process,

$E_{ik}(t)$ = the rate land entering improvement process in each year.

There is another reason that unit cost would be an increasing function of time. Costs related to the use of heavy equipment may decline over time. On the other hand, it is quite certain that the wage rate would increase more rapidly, so the two factors may not compensate each other. Hence, total unit costs are assumed to be increased by a rate of APPA. Thus, Equation 4.18 actually used unit cost function should be read:

$$4.20 \quad APSC_{ik}(t) = [APS1_{ik}(t) + APS2_{ik}(t)]/2.0 * \varepsilon^{APPA * t}$$

The exact mathematical relationship between unit cost and accumulated land is not pursued here since interpolation or extrapolation by computer is well developed [See (L.19)]. For present purposes, TABLIE function is chosen, and calling statement to this function in FORTRAN is:

```
4.21  APS1 (1,K) = TABLIE [VALCT (1,K), SMALL, D1 (I,K),
                   KCOST (I,K), S(I,K)]

4.22  APS2 (1,K) = TABLIE [VALCT (1,K), SMALL, D1 (I,K),
                   KCOST (I,K), TL (I,K)]
```

Where:

VALCT (1,K) = an array of unit costs or function values derived from Figure 4.1 corresponding to each segment of independent variable,

SMALL = the smallest value of independent variable defined, the origin value,

D1 (I,K) = interval of independent variable augument, KCOST (I,K) = the number of segments of independent variable divided,

S (I,K) and TL (I,K) are $S_{ik}(t)$ and $TL_{ik}(t)$ in FORTRAN statement, respectively.

We distinguish three types of public budget: intended investment, desired investment or implementation budget, and realized investment or actual budget. Project completion is often delayed beyond a necessary gestation period because the desired investment is not realized. This, in turn, requires more investment.

At any rate, the intended investment is assumed to determine the rate of land entering improvement processes in each year, is exogenously decided by public resource administrators, and termed here $B_{ik}(t)$. The rate of land entering project implementation, $E_{ik}(t)$ is:

$$4.23 \quad E_{ik}(t) = B_{ik}(t)/APSC_{ik}(t)$$

Where APSC is average unit cost. Required investment or the implementation budget for each year, $TCPD_{ik}(t)$, can be computed as follows:

$$4.24 \quad TCPD_{ik}(t) = [ASPC_{ik}(t)/DELPP_{ik}] * STRGP_{ik}(t)$$

Where:

$DELPP_{ik}$ = normal average expected time delay to implement project,

$STRGP_{ik}$ = total land under implementation process computed in Equation 4.6.

An implicit assumption is made here that budget requirement is uniformally distributed over the time period between initiation and completion of land improvement.

The main purpose of the public investment is to play an important role in shifting the production function among subfunctions, hence, product supply and factor demand functions. This shifting can be defined in several ways, depending on the production function defined.

Because of the way production function and derived projection equation are defined in Chapters VI and VII, we transform the variables in Equations 4.6 - 4.14 into the rate of change in various land classes.

1. Rate of change in perfectly irrigated paddy:

$$4.25 \quad SCR_{i1}(t) = [PITP1_i(t) - PITP1_i(t-1)]/PITP1_i(t-1$$

2. Rate of change in semi-perfectly irrigated paddy:

$$4.26 \quad SCR_{i2}(t) = [PITP2_i(t) - PITP2_i(t-1)]/PITP2_i(t-1)$$

3. Rate of change in temporary irrigated paddy:

$$4.27 \quad SCR_{i3}(t) = [PITP3_i(t) - PITP3_i(t-1)]/PITP3_i(t-1)$$

4. Rate of change in consolidated paddy:

$$4.28 \quad SCR_{i4}(t) = [RCP_i(t) - RCP_i(t-1)]/RCP_i(t-1)$$

5. Rate of change in drained paddy:

$$4.29 \quad SCR_{i5}(t) = [RDP_i(t) - RDP_i(t-1)]/RDP_i(t-1)$$

6. Rate of change in consolidated upland:

$$4.30 \quad SCR_{i6}(t) = RCU_i(t) - RCU_i(t-1)$$

7. Rate of change in irrigated upland:

$$4.31 \quad SCR_{i7}(t) = RIU_i(t) - RIU_i(t-1)$$

Where:

$PIIP_{ij}(t)$, $j = 1,3$ = proportion of the first three types of irrigation to total paddy in each region, respectively

$RCP_i(t)$ and $RDP_i(t)$ = proportion of consolidated and drained paddy to total paddy, respectively

$RCU_i(t)$ and $RIU_i(t)$ = proportion of consolidated and irrigated upland to total upland, respectively.

Note that paddy irrigation type 4, which is rain-fed, unconsolidated, undrained paddy, and unconsolidated, unirrigated upland have not been transformed into the rate of change because these variables are not supposed to shift the production function. These variables, defined in Equations 4.25 - 4.31, are termed as structural changes in the land and water development subcomponent.

Also note that the last two equations are computed differently than the previous ones for technical reasons. These two projects, upland consolidation and irrigation, are assumed nonexistent prior to 1970, so initial values of RCU and RIU are zero. On the other hand, the production function adapted in this study, as presented in Chapter VI, is a type of Cobb-Douglas production function, having the ratios of improved land to total land as independent variables. The logarithm of the zero value is not defined. This problem can be solved in some way. The truly difficult problem is that the rate of change in ratios for this particular case turns out very large, such as 100 or 200 percent, at the beginning of the planning horizon. Then the production response is overestimated with a constant production elasticity. Thus, for these two variables, and variables of $SLDR_{i1}$ and $SLDR_{i2}$ changes in the ratios of developed new land to appropriate total land discussed in the preceding page, the time-varying elasticities are applied as we will see in Chapter VI.

Among land and water development projects, tideland development ($k = 1$) and upland development ($k = 2$) are designated to augument paddy and upland, respectively. Can the productivity of this new land be assumed to be constant or the same as that of old, existing land without losing generality? It is quite certain that, while other land and water development projects act to shift the production function among subfunctions upward and rightward, these two projects in fact act to shift the production function among subfunctions downward and leftward. This is because the productivity of new land is generally low, so the more new land a region has in cultivation, the more low average productivity will be realized in the region.

To more accurately deal with productivity growth over time, we assume that new land productivity will grow as follows: the first year's productivity will be 30 percent of existing land productivity; second-year productivity will be 35 percent; 45 in the third-year productivity; fourth-year productivity will be 60 percent; fifth-year 80 percent; and sixth-year 100 percent. This productivity growth rate is termed WG_j.

To compute a weighted average productivity of the new land, we first compute total land developed during the past five years, including the current year. For example, for tideland development:

$$4.32 \quad SDTYR_i(t) = \sum_{j=o}^{4} DSC_{i1}(t-j)$$

Then we compute the sum of weighted productivity as follows

4.33 $WPTLD_i(t) = \sum^{4} WG_j * DSC_{i1}(t-j)$

Where:

$WPTLD_i(t)$ = sume of weighted productivity of tideland,

WG_j = weight given to land developed in each year.

Finally, the weighted average productivity of new land, $WAP_{i1}(t)$, is computed:

4.34 $WAP_{i1}(t) = WPTLD_i(t)/SDTYR_i(t)$

As we computed structural change variables in Equations 4.25 - 4.31, we also transform total new land into the rate of change. First, the relative quantity of new land to total paddy for tideland and development and total upland for upland development is computed, respectively:

4.35 $RTD_i(t) = SDTYR_i(t)/TPLAND_i(t)$

4.36 $RUD_i(t) = SDUYR_i(t)/TULAND_i(t)$

The rate of change of new land is

4.37 $SLDR_{i1}(t) = [RTD_i(t) - RTD_i(t-1)]$

4.38 $SLDR_{i2}(t) = [RUD_i(t) - RUD(t-1)]$

Thus, it is equivalent to saying that region-wide average productivity will decline if new land is added by:

4.39 $PRNL_{i1}(t) = WAP_{i1} * SLDR_{i1}(t)$

$$PRNL_{i2}(t) = WAP_{i2} * SLDR_{i2}(t)$$

A crop-specific model will appear in Chapters VI and VII.

In summary, this model component, together with the model in the next chapter, has been designed for product supply and factor demand projection. Therefore, all output variables for the model components described in this chapter can be said to be intermediate output variables. The variables that will be transferred directly to other subroutines are:

$TLAND_i(t)$ = total agricultural land

$SCR_{ik}(t)$ = rate of change in the proportion of each kind of improved land to total paddy or upland, respectively

$APSC_{ik}(t)$ = average project unit costs

$DSC_{ik}(t)$ = land area improved in each year

$WAP_{i1}(t)$ = weighted average productivity of new land

$SLDR_{i1}(t)$ = rate of change in relative area of new land

As seen above, the major output variables of the public subsector component modeled in this chapter are: (1) total agricultural land, paddy, upland or a combination, and (2) accumulated land improved in terms of irrigation, consolidation and drainage. In other words, the model component described in this chapter is capable of simulating behavior of these variables over time, based on alternative public policies, especially in terms of public investments in various land and water development projects, and in terms of alternative land use policy in relation to agricultural land disappearance. This model component can also simulate consequences of alternative patterns in allocating actual investment in relation to desired investment as will be discussed in Chapter VIII.

In summary, this model component is relatively simple in terms of model structure and data requirements. Fewer restrictive assumptions are required. There are four major parameters in this public subsector model that will probably affect the behavior of the output variables: Unit costs, average expected time required to complete each project, fraction of land required to insert some land-improvement structure, and land disappearance due to urbanization. These variables or parameters (except the last one) are technical ones, so the engineer can provide additional information on the related data in nature. In short, data improvement and support for collecting data are needed for model improvement.

CHAPTER V

PUBLIC INVESTMENT--BIOLOGICAL RESEARCH AND EXTENSION

This is the second chapter on the public investment sector. First, we will develop a primitive model of the biological research subsector, consisting primarily of a table of possible research outcomes from indicated research investments. Much more attention will be given to the third section, where we construct a social diffusion model of research outcomes. This mathematical social diffusion model is based on some useful decision-making theories and earlier work done by the systems simulation team at Michigan State University. These will be reviewed in the second section. This subsector model is essentially independent of the land and water development subsector model with some minor exceptions, although both subsectors compete for public investment funds. Interaction with output variables from both model components and subsectors will be presented in the next two chapters.

Biological Research Subsector

It seems that there exists a functional relationship between research outcome and research investment. However, it also seems that research productivity is not well known. Furthermore, research outcome seems to have a large probability or confidence range. The research outcome appears to involve high uncertainty or risk. The productivity and confidence range for its probability distribution seems to depend on many other things, such as accumulated knowledge, coordination among specialized disciplines, development of knowlege in other continents or countries, etc. What is emphasized here is that the research outcome is not only a function of the current domestic public investment, but also a function of past investment, domestic or abroad.

Evenson [E.3] formulates a production function as a function of these two types of investment in addition to other variables. Hayami and Ruttan [H.9, part 4] discuss the extent to which biological technology can be transferred among countries. Moseman [M.21] discusses building biological research systems. At the same time, Fishel [F.6] presents several articles by different authors dealing with economics of biological research.

Despite much work on the economics of biological research, the common conclusion seems to indicate that social returns to public investment in research are high. The impression is that they have studied only successful cases. The analytical framework for coming to this conclusion seems to have been primarily the cost-benefit analysis technique. Examples are found in Griliches [G.8]and Peterson [P.5] and Schultz [S.4] summarizing this part of the study, done mainly by Chicago school people. We do not follow this analytical framework. The reason is very simple: first of all, we intend to model how economic variables dynamically interact with each other to capture all possible direct and indirect effects of research activity. Secondly, we intend to project yields rather than examine the internal rate of return.

Biological research in the Korean agricultural setting can be classified into three basic categories:

1. Basic and environmental research
2. Breeding
3. Culture

All this research aims at a set of common goals. These goals can be put into two groups: desirable or "good" outputs, and undesirable or "bad" outputs.

1. Desirable outputs:
    a. Yield increase
    b. Uncertainty reduction
    c. Quality improvement
    d. Early maturity
    e. Savings in production factor requirements
    f. Others
2. Undesirable outputs:
    a. Increase in material costs
    b. Increase in labor requirements
    c. Increase in uncertainty
    d. Increase in credit needs
    e. Others

Various combinations of desirable and undesirable outputs can be brought about by research activities. What would the shape of production function of public investment be in terms of the research outcomes listed above? What would the productivity coefficient of public investment be?

One way to estimate this productivity coefficient is regression analysis, using time series data where yield or other variables are dependent variables and public investment or expenditure is an independent variable. The independent variable may be lagged or accumulated public investment in agricultural research. There are several difficulties with this approach. First, past experience is not always repeated in the future. Second, the production function shifter, scientific findings abroad and training are important. Training abroad is not necessarily financed by the Korean government.

All this implies that at least some of the public investment in other countries must be counted as independent variables in the production function. A further complication is that agricultural research is a sort of joint product enterprise.

A more systematic modeling of agricultural research systems might well become a good topic of another Ph.D. dissertation. To make the model presented in this study manageable, we adopt a pragmatic approach. That is, the first assumption is that the research outcome is a sort of package having certain combined levels of attributes in terms of the outcomes listed above. The second assumption, which is more crucial is that a planned agricultural research outcome would be realized.

A hypothetical set of planned research outcomes for each crop or crop group appears in Table 5.1. The figures indicate the average productivity gain. These figures do not directly represent the productivity gain at the experiment station level. Suppose the productivity gain of a research outcome is 30 percent above that prevailing at the time. Also, suppose that this particular technology can be disseminated to 50 percent of the area in the region with a gain in

Table 5.1. Hypothetical Planned Expected Research Results in Terms of Rate of Increase in Yield at Experiment Station Adjusted by Proportion of Land Where Results Could Advantageously be Used.

Year	Rice	Barley	Wheat	Other Grain	Fruit	Pulses	Vege-table	Potato	Tobacco	Forage	Silk	Indus-trial Crop	Grass
1971	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.05	0.05	
1972													
1973													
1974	0.05					0.10	0.05	0.10	0.05	0.15	0.05	0.05	0.05
1975													
1976		0.15	0.15	0.15	0.10								
1977	0.15						0.15	0.15	0.05	0.15	0.05	0.05	0.15
1978		0.05	0.10			0.15							
1979	0.05												
1980							0.15	0.15	0.05	0.15	0.05	0.05	0.10
1981				0.15	0.10								
1982	0.15	0.10	0.10			0.10							
1983							0.10	0.10	0.05	0.15	0.05	0.05	0.15
1984													
1985													
Total	0.50	0.35	0.40	0.35	0.25	0.40	0.50	0.55	0.25	0.70	0.25	0.25	0.45

productivity. Then the average regional productivity gain would be 15 percent (0.3 x 0.5 = 0.15). In other words, the figures in the table are interpreted as computed by multiplying productivity gain at experiment station by proportion of land where results could advantageously be used. The research outcome for a crop can come about more than once during the planning horizon (1971-1985).

In the computer program in Appendix A, $RYINCR_{ijk}$ stands for the productivity increase at the experiment station, $RYDISS_{ijk}$ for disseminable area in proportion, and $RYDIFF_{ijk}$ for the average productivity gain, where i = 1, 3 for regions, j = 1, 13 for crops and k = 1, 5 maximum for the number of research outcomes. The variable $IBEXYR_{ijk}$ stands for the year in which k^{th} research outcome for j^{th} crop in i^{th} region is materialized and ready to be disseminated.

As pointed out earlier, agricultural research is a highly risky enterprise. In other words, it is highly uncertain as to when a disseminable research outcome will take place at what level, with what attributes and with what effects on total accumulated productivity gain during the planning horizon. As Johnson, et al. [J.15] correctly point out, there are numerous possible decision-making rules for a highly risky enterprise. We can hypothesize the consequences of alternative courses of action or assumptions. That is, the disseminable research outcomes with certain levels of productivity gains at given points of time postulated in Table 5.1 will be treated as a starting point. What will happen if actual research outcomes are different from this situation in terms of timing, productivity gain at each point of time when the research outcome is materialized, or accumulated productivity gains achieved during the planning horizon? We will come back to this issue in Part III, when we discuss sensitivity analysis and policy experiments.

Theory of Innovation Diffusion

The research outcomes defined in Table 5.1 are interpreted as at experiment stations, not at farms. They must be communicated to individual farms through diffusion channels, such as the extension service. Diffusion of innovation does not take place entirely spontaneously. Hence, we need to model the media that channel information about this innovation to materialize the potential productivity gain. Diffusion of an innovation does not take place instantaneously. The condition of the experiment station in terms of agricultural resource base is likely above that of the average individual farm. These are some reasons why the actual productivity gain at individual farm levels may be considerably less than that at experiment stations. With a given research outcome having given attributes, the rate of diffusion and hence, actual productivity gain, will depend on the magnitude of the stimulant if other conditions remain unchanged. In the next section, we will present a social diffusion model to describe the interaction among research outcomes, stimulant, diffusion rate and change in actual productivity gain at the farm level.

First, however, we review some useful theories on decision-making and diffusion, in economics as well as sociology. According to Johnson [J.10], a problem-solving-oriented decision-making process can be shown in a diagram as in Figure 5.1. There are six steps or subprocesses involved in making a decision. This diagram shows that

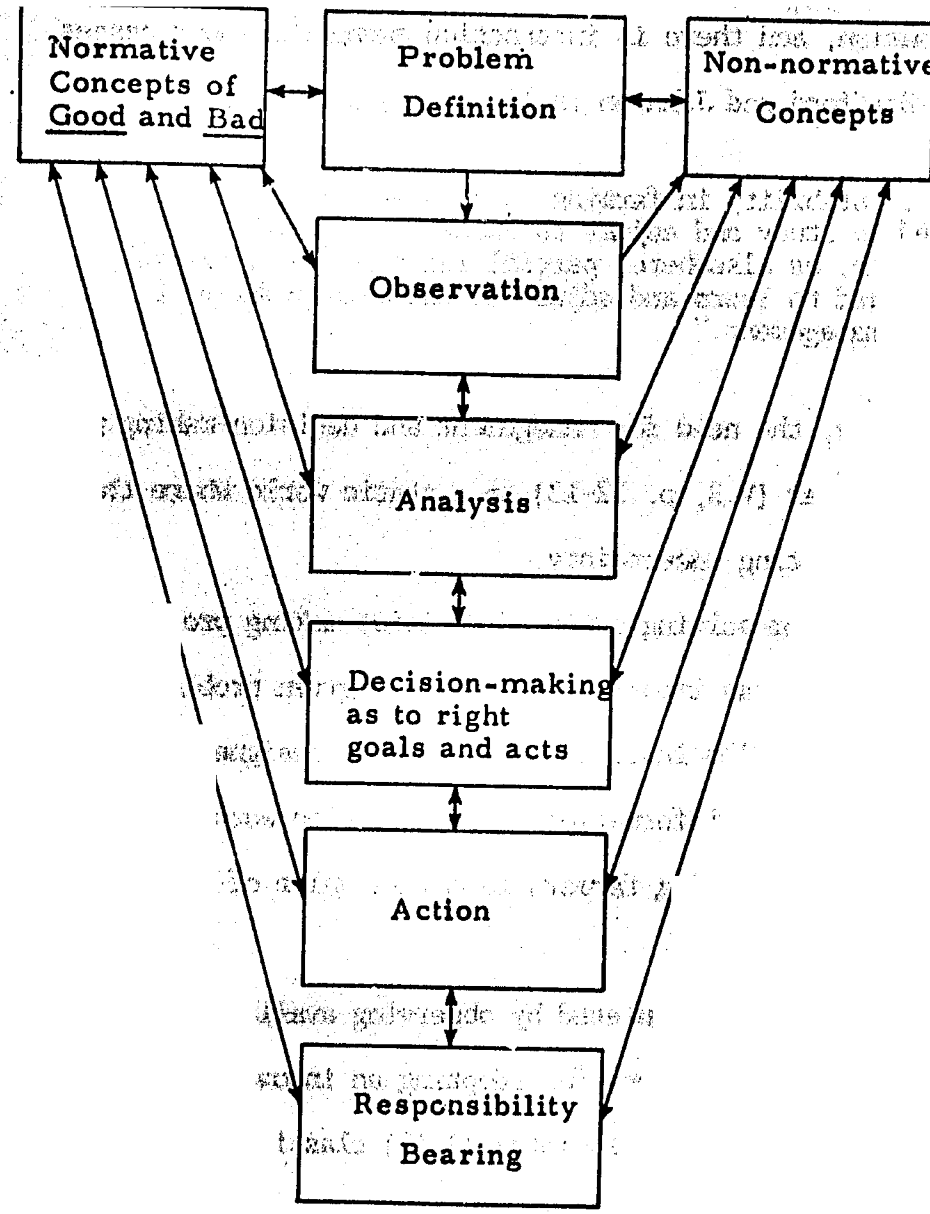

Figure 5.1. Six steps in a problem-solving process. (Source: Adapted from A Study of Managerial Processes of Midwestern Farmers, Johnson, G. L., Halter, A. H., Jensen, H. R., Thomas, D. W. Iowa State University Press, Ames, Iowa, 1961. See also "The Role of the University in Economic Development," J. S. McLean Visiting Professor Lecture, Department of Agricultural Economics, University of Guelph, Publication No. AE 70/2, March 23, 1970.)

problem-solving-oriented decision-making is an iterative process, each subprocess interacting with normative as well as non-normative concepts or information, and there is interaction among the subprocesses.

As Bradford and Johnson [B.14, p. 15] point out,

> ". . .stability in farming is abnormal--change and the need to study and adjust to change are normal. In farming, as elsewhere, partial ignorance is universal; the need to learn and adjust is the main problem of farm management."

In other words, the need for management and decision-making would largely disappear [V.3, p. 12-13] in a static world where there is no change and resulting uncertainty.

In a problem-solving-oriented decision-making process, the observation phase plays an important role with a given problem definition. In fact, the extension institution is largely designed to help farmers gather the necessary information. The extension worker also plays an important role in helping farmers formulate value of problem definitions [J.7].

The knowledge accumulated by observing available information is critical in making decisions for adopting an innovation or a new technology. Johnson and his associates [J.13] classify the knowledge situation as follows:

1. Certainty; positive as well as negative
2. Inactive situation
3. Learning situation; voluntary as well as involuntary
4. Forced action situation; positive as well as negative
5. Subjective risk situation; positive as well as negative.

Inactive, learning and forced action situations together are often called uncertainty. That is, they are classified as modified version of Knight's knowledge classification of certainty, uncertainty and risk. Whether a farmer adopts an innovation or not is exclusively determined by the knowledge he gathers, other things being equal. This knowlege situation can, of course, be altered by observing available information. Johnson and his associates [J.13] discuss the type of information source in detail. The idea of communicative and noncommunicative sources is directly adopted in formulating the diffusion model presented in this chapter.

Before making a firm decision, the message receiver needs to analyze the available information. In this analysis phase, it seems that the economist tends to emphasize the economic variable exclusively as the subject matter of analysis, whereas the sociologist claims that sociological factors are more or at least equally important, depending on specific situations. Griliches [G.6] and Schultz [S.2, p. 164] claim, respectively, that profitability or an economic variable is a strong explanatory variable or major determinant for adopting a new technology or innovation. Schultz adds, "it is not necessary to appeal to differences in personality, education, and social environment."

The same sort of idea is expressed by Griliches: .in the long run, and cross-sectionally, [sociological] variables tend to cancel themselves out." Both scholars are criticized by a sociologist, Rogers [R.2, p. 143-144], for their extreme position. At the same time, Mellor [M.] emphasizes uncertainty or risk consideration as being equally important in the adoption behavior of peasants. Some examples of sociological variables considered important in explaining adoption or rejection of a new idea, innovation or technology are found in Bowden [B.12], Moulik and Lokhande [M.26], Feaster [F.2], Fliegel, et al. [F.8], Chattapadhyay and Pareek [C.2], Havens [H.6], etc.

The sociologist does not completely exclude economic variables in his model, however. A good example is found in Fliegel, et al. [F.8]. Johnson, et al. [J.13] identify different kinds of information used by farmer decision-making.

Rogers [R.5, p. 137-160] discusses the type of perceived innovation attributes that affect the rate of adoption. The main points he makes can be summarized as follows:

1. Relative advantage, in terms of monetary as well as non-monetary matters.
2. Compatibility, in terms of values and needs, as well as idea or technology previously introduced.
3. Complexity
4. Triability
5. Observability.

As far as seed technology for a major crop is concerned, it is not hard to believe that the new technology would be disseminated rather rapidly, since all criteria advanced by Rogers are likely to be fulfilled. In other words, economic variables might be said to be the main variables affecting diffusion rate in the long run in this instance. In this sense, Griliches and Schultz are right since both are primarily concerned with seed technology, although there could be an exceptional case for a subsistence crop [see, Rogers (R.5, p. 142-149].

On the other hand, Rogers [R.5, p. 183-185] presents adoption cateogries as follows:

1. Innovators (first 2.5 percent of adopters)
2. Early adopters (next 13.5 percent of adopters)
3. Early majority (next 34 percent of adopters)
4. Late majority (next 34 percent of adopters)
5. Laggards (last 16 percent of adopters)

This characterizes the shape of adoption rate distribution curve. This curve, based on the figures given above, is a bell-shaped normal distribution, and the cumulated frequency distribution is S-shaped.

In reality, however, it seems that the level of the perceived attributes of an innovation determines the specific shape of the adopter distribution curve. That is, the magnitude of the perceived attributes seems to contribute greatly to the determination of the mean, standard deviation and skewness of the distribution, or parameters of Erlang family of probability distribution, K and D in Equation 4.3.

Nevertheless, Rogers [R.5, p. 179] concludes that "It has generally been found that adopter distributions follow a bell-shaped curve over time and approach normality." Is this conclusion true regardless of changes in aspiration, value system, level of perceived attribute of an innovation, degree of fulfillment of needs, level of stimulant, etc.? Is there an alternative form of adopter distribution, adapted to a more specific environmental condition? It would seem that a bell-shaped normality curve prevails in a case where diffusion takes place more or less spontaneously, there are many alternative means to satisfy a need, the society is more or less in a stationary situation, and there is not much stimulant in adoption, even if the perceived attribute is real.

As a matter of fact, Perry and his associates [P.4] in a diffusion research report say that "A generally accepted belief is that adoption of new farming practices follows as S or growth curve," and concludes by saying that, "Perhaps in American society, at least, innovation is rapidly becoming the norm and the diffusion curve will soon more nearly approximate a J-curve than an S-curve." What is being said here is that the diffusion curve can be a J shape if certain conditions are met even in a less developed country; productivity gain is high with little uncertainty, the relative price is sufficiently in favor of adoption, an adequate amount of information is supplied, and so on.

This argument does not deny the usefulness of adopter categorization as advanced by Rogers. One may find some innovators and venturesome or progressive farmers in any society. The progressive farmer adopts innovations first. Once he is successful, the diffusion process speeds up rapidly. Rogers [R.5, p. 185-187] generalizes socioeconomic characteristics of the innovator. Nevertheless, there is a report [Malone (M.1)] that finds no difference in adoption rate of a package program in India between social status classes.

As implied in Figure 5.1, decision-making in adopting a new technology involves an iterative process. According to Campbell [C.1], the traditional model of the individual adoption process currently used is a five-stage model: (1) awareness, (2) interest, (3) evaluation, (4) trial, and (5) adoption. After criticizing this traditional model, he advances an alternative model called the adoption tree. This model is illustrated in Figure 5.2

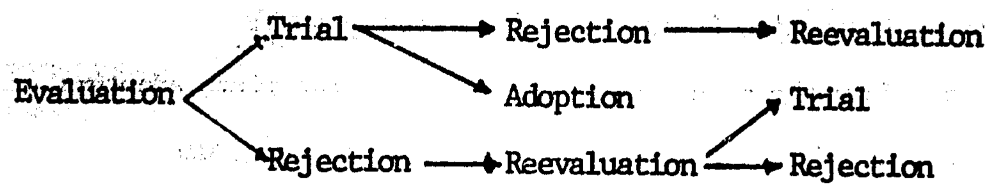

Figure 5.2. A model of individual adoption process--The Adoption Tree.

According to this model, the analysis or evaluation leads to two alternative decisions: one to trial and the other to rejection. The trial also leads to alternative decisions: to adoption which means the perceived attribute of the innovation proved advantageously or the innovation fits the individual farm situation or practice, or rejection, which implies that the innovation is not advantageous to the specific farm situation, practice or both. As far as an innovation turns out profitable to at least some farmers, the re-evaluation process will be repeated several times until the knowledge situation becomes certain, while adjusting individual farm practices. If an innovation is profitable to some farmers and there is a need that can be satisfied by adopting it, the innovation eventually will be adopted by the whole population, regardless of the price level. A good example is the case of hybrid corn in the United States.

The trial stage can be viewed as an adoption in a broad sense. Some find the innovation viable, but not all. Rejection after trial may be called dropout. This dropout is not a consequence of a decrease in the relative price of the crop.

Kislev, et al. [K.5] might call this drop out a process of an innovation cycle. They define an innovation as either a new product or production method that appreciably affects the supply of an existing product. As an innovation is adopted, the industry supply increases, by definition. Then the price level will drop, so the first adopters will be driven out of the production of the new product or use of the new method according to Kislev, et al. They call this process an "innovation cycle."

The proposition that what is good for the individual firm is also good for the industry does not often hold for a competitive industry like agriculture. As Cochrane [C. , p. 949] points out, despite the industry's depression, the individual farm continues to adopt the new technology. Suppose that, due to a new technology, industry supply has expanded until the price level has dropped, say, by a third. Suppose also that the new technology produces a 30-percent higher yield with negligible cost increase. Should the first adopters stop using the new technology? It is quite possible that they can restrict area allocated to this particular crop. But they will never stop using the new technology as long as they produce the same crop.

Cochrane [C. p. 96] puts the matter this way:

> "To stay even with the world these average farmers are forced to adopt the new technology. The average farmer is on a treadmill with respect to technological advance."

he continues

> "In the quest for increased returns, or the minimization of losses, which the average farmer hopes to achieve through the adoption of some new technology, he runs faster and faster on the Treadmill. But by running faster he does not reach the goal of increased returns; the treadmill simply turns over faster."

What Kislev, et al. talk about sounds like a production cycle, not an innovation cycle. The production cycle can be observed for a certain class of products in any country (see recent articles such as Talpaz [T.1], Meadows [M.8], and Huh and Lee [H.28].)

It seems that we are now equipped with absolute minimum amount of diffusion theory to be ready to model a social diffusion model of innovation. Before describing the mathematical diffusion model advanced in this study, let us quickly look at how a system scientist or economist using a system science approach could deal with the social diffusion process. The literature reviewed here is exclusively the work of Manetsch and his associates.

The social diffusion process is often discussed under the heading of modernization program in their works. There seem to be a variety of modernization models. The modernization model of Brazilian textile industry by Manetsch, Ramos and Lenchner [M.5] seems to assume that promotion is not required. In this sense, the model can be said to be an equilibrium model, since the supply is always equal to demand. However, the modernization model of the beef herd management sector in Brazil by Lehker and Manetsch [L.13]is different in nature. This model allows both necessity of promotion and assumes a lagged response. This is a disequilibrium dynamic model, since supply exceeds demand, and a dynamic model since the response does not take place instantaneously.

The modernization model of cotton production in Brazil by Manetsch, Ramos, andLenchner[M.3] seems to be the first study of a social diffusion process linked directly with a research sector and modeled with the systems simulation approach. Modernized land that now uses a new technology is modeled by a higher-order differential equation such as Equation 4.3 and stimulated by extension effort, together with other variables. Modernized land is supposed to update the yield level, which is a function of public research expenditure accumulated, without additional extension effort. Then, the technical assistance from extension workers, credit requirements and total modernization costs are computed.

A more interesting feature of the model is an attempt to compute some sort of cost-benefit ratio of the modernization program; total costs being research expenditures plus other modernization costs required, and benefit being defined as the public revenue increase due to a high productivity. The nature of this cost-benefit analysis is viewed from the standpoint of the public sector alone. In fact, the existence of a public sector is justified by its externaltiy. In general a public expenditure can rarely be justified by this nature of the cost-benefit analysis, without counting external or indirect effects. Otherwise, it would be quite possible for a profit-motivated private firm to enter the market.

A social diffusion prototype model appears in Manetsch and Park [M.6, Ch. 15], constructed after several years experience. A representative application of this model is found in the Nigerian agricultural sector simulation model by Manetsch, et al. [M.4]. Since this model is more realistic and a later version by Manetsch and his associates, and since the model presented in this study is a departure from this model, we will review it more thoroughly here. The causal flow chart of the Nigerian modernization component is reproduced here as Figure 5.3.

As seen in this flow chart, there are three major processes in the diffusion of a new technology. The dissemination process is

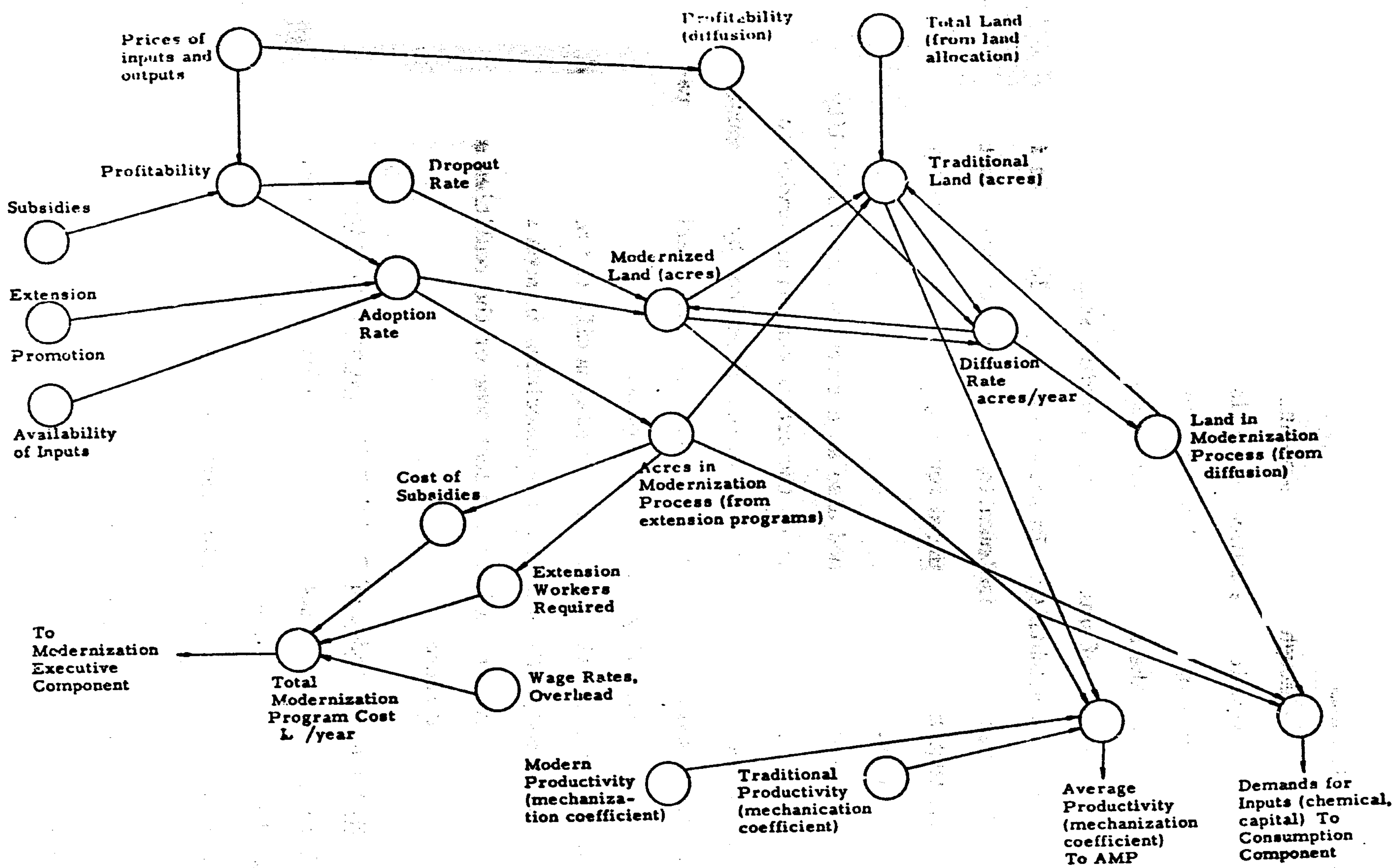

Figure 5.3. A causal diagram of the modernization component (applies to crop modernization and introduction of mechanization)--arrows indicate direction of causality.

divided into two categories: (1) adoption due to promotion by the extension service through direct communication, and (2) dissemination through the noncommunicative source, which is termed the diffusion process in the original report. The third process is the dropout or rejection process. The adoption through communication source is defined as a function of profitability, including subsidies, extension effort and input availability. In actuality, they rule out the input availability constraint in implementing the simulation run. Instead, they assume that the input required for adopting a new technology will be supplied.

The dropout rate is defined also as a function of profitability without subsidies, and the ratio of the actual extension service to the required one. The diffusion rate is now determined by the amount of modernized land and profitability. Then, as usual, various requirements, modern productivity, etc., are computed.

In summary, we will extend and slightly modify the model of social diffusion advanced by Manetsch and his associates in such a way as to adapt it to the present study and reflect some of the realities and theories discussed above.

Mathematical Model of Social Diffusion of Innovation

First, we discuss a model of social diffusion of an innovation. Then we discuss computation of the average yield increase due to innovation dissemination, taking into account interaction with the resource base.

The overall flow chart of an innovation dissemination process hypothesized here is shown in Figure 5.4. Remember that we have a

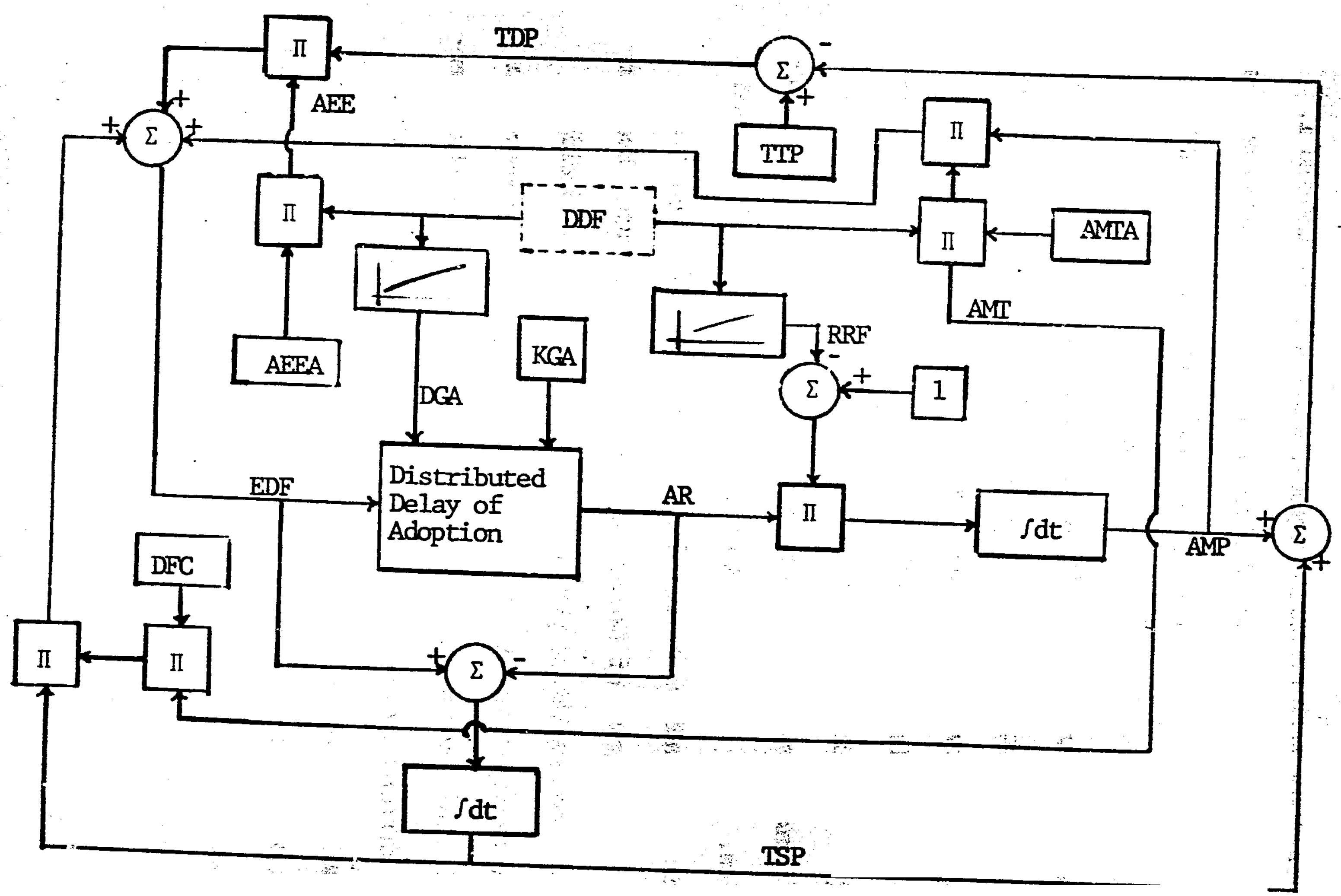

Figure 5.4. Flow chart of innovation diffusion process (hypothetical).

maximum of five research outcomes during the planning horizon, which will be indexed k; for each of 13 crops or crop groups, which will be indexed j; and for each of three regions, which will be indexed i. What the flow chart in Figure 5.4 shows is the diffusion process of a single research outcome or innovation, which comes about at a given point of time for a crop and for a region.

Will the diffusion of an innovation take place instantaneously? Do all farmers adopt an innovation at the same time? Does the extension institution try to disseminate new knowledge to all farmers right after the new knowledge is materialized? In practice, whenever a new technology comes out, the extension agency will try to introduce it first to a small number of farmers with favorable socioeconomic characteristics. This is due to a limitation of manpower, budget, seed multiplication capacity, or even knowledge of the technology itself.

This first group of farmers may be called innovators. Even for innovators, some gestation period is required in order to decide whether to adopt or reject the new idea, or whether more observation is needed. This gestation period will differ, depending on characteristics of different farmers, including their knowledge situations. This means that perhaps the adoption of a new idea by the innovator class can be crudely modeled by a distributed delay model rather than a discrete delay model. As shown in Chapter IV, a distributed delay process can be modeled by a higher-order differential equation that has the same property as the Erlang family of probability density functions. As indicated in Chapter IV, there are a variety of DELAY subroutines. But here the DELDT subroutine is chosen for solution stability of the delay output, and to use the time increment DT = 1.0 for the efficiency consideration. However, the DELDT subroutine is found to incorrectly compute the delay output for this particular model.[1] Thus we have slightly modified that subroutine and called it DELDD. DELDD appears in Appendix A, together with other subroutines. The call statement of this subroutine is:

5.1 CALL DELDD [EDF(I,J,K), GA(I,J,K), RGA1(I,J,K,), DGA(I,J,K) DIGA(I,J,K), DT, KGA, AR(I,J,K)]

EDF_{ijk} = rate of land entering the delay process for the k^{th} research outcome for the j^{th} crop and for the i^{th} region at a given time.

GA_{ijk} = rate of land leaving delay process (unmodified)

AR_{ijk} = modified GA_{ijk}, delay output rate

RGA_{ijk} = intermediate rate in delay process

DGA_{ijk} = time length of delay

$IDTGA_{ijk}$ = fraction of time increment, DT, needed to make the output stable

DT = time increment

KGA = order of differential equation.

Once we know the input and output rates of the delay process, total land in the process of adoption can be easily computed using a

---

[1]The DELDT subroutine assumes a smooth and continuous input rate, which is termed here EDF, over time. However, in this particular model, the input rate changes rapidly in the beginning of diffusion process. This causes trouble with computing delay output correctly, termed here GA. What is modified is that a mechanism to correctly compute the output rate is added inside the subroutine. This modified output rate is termed AR, and is used to compute related state variables such as modern land, which is termed here AMP, as stated in the text.

simple integration formula as done before. This variable is termed TSP, and is computed by summing the intermediate rates, RGA, after other parameters into consideration, instead of integrating the difference between input and output rates. That is:

$$5.2 \quad TSP_{ijk}(t) = \sum_{m} RGA_{ijkm}(t) * IDTGA_{ijk}(t) * DGA_{ijk}(t)/KGA$$

The accumulated land that has a new technology, termed AMP, can be computed as follows:

$$5.3 \quad AMP_{ijk}(t) = AMP_{ijk}(o) + \int_{o}^{t} AR_{ijk}(t)\, dt$$

Where: AR_{ijk} is the delay output.

Once the transition and modern land are known, the land remaining with a traditional technology, termed TDP, can be computed as follows:

$$5.4 \quad TDP_{ijk}(t) = TTP_{ijk}(t) - AMP_{ijk}(t) - TSP_{ijk}(t)$$

Where: TTP_{ijk} is total land.

What kinds of factors determine the rate of input, or land entering the delay process (EDF), the time length of delay (DGA), dropout rate (RRF), and the order of the delay (KGA)? Would these variables be constant over time regardless of the level of extension promotion, perceived level of the research outcome, importance of the crop, degree of regional specialization, etc.? It is known empirically that behavior of the delay output is not very sensitive to the order of the delay KGA, in the range between 5 and 10. Thus, the rest of the variables (input rate (EDF), length of the delay (DGA) and dropout rate (RRF) are hypothesized here as some function of:

1. Distributed lagged extension effort for a specific crop in each region, in terms of budget (BEXD). The distributed lag value is used since it is believed there would be some carry-over effect.
2. Long-run profitability of the specific crop (PROFTY).
3. Change in the long-run profitability (PROFCH).
4. Size of crop in a region in terms of area planted (SZC).
5. Degree of regional specialization (RSP).
6. Level of specific research outcome (RYDIFF), which is defined as the expected rate of increase in yield when it is materialized, in earlier material in this chapter.

What would the exact functional form between each of the dependent variables and the set of independent variables cited above be? The exact functional relationship is not well known. However, it is not hard to conceive that: (1) the higher the level of the research outcome and the larger the input rate, the shorter the length of delay we can expect, and so on, (2) the dependent variable may not be a linear function of individual independent variables, etc. For simplicity, we derive one common factor $DDF_{ijk}(t)$, to link the dependent variables with independent variables, and hypothesize the following relationship:

$$5.5 \quad DDF_{ijk}(t) = ROEDF_{ijk}(t) + ROEDF_{ijk}(t)\ [EEEDF_{ij}(t) + \{PFEDF_{ij}(t) + PCEDF_{ij}(t) + CSEDF_{ij}(t) + RSEDF_{ij}(t)\}]$$

Where:

$ROEDF_{ijk}(t)$ = effect of research outcome on diffusion for k^{th} outcome for j^{th} crop and i^{th} region

$EEEDF_{ij}(t)$ = effect of extension effort on diffusion

$PFEDF_{ij}(t)$ = effect of profitability on diffusion

$PCEDF_{ij}(t)$ = effect of profitability change on diffusion

$CSEDF_{ij}(t)$ = effect of crop size on diffusion

$RSEDF_{ij}(t)$ = effect of regional specialization on diffusion

Note that (1) when the effect of the research outcome is zero, DDF is equal to zero (2) where no extension effort is given, research outcome is the only variable that affects DDF, and (3) extension effort is designed to supplement research outcome and other variables supplement these two variables. Johnston and Southworth [J.20] point out that "agricultural extension, for example, pays little return unless and until research has produced and tested profitable innovation to extend." This belief is directly adopted in this formulation.

Precisely what are all these effects? It is sufficient to illustrate for two variables only how weights are assigned to each variable, since the necessary data for the other variables are given in the computer program. Let us see how the weight system is constructed for research outcome effect (ROEDF) and extension effort effect (EEEDF). As seen in Figures 5.5 and 5.6, the weight given to the research outcomes and extension effort is, respectively, a function of research outcome and extension effort. The weight, however, is not a linear function. Then, RDEDF, EEEDF and other variables are interpolated by means of the TABLIE function. For example, for ROEDF:

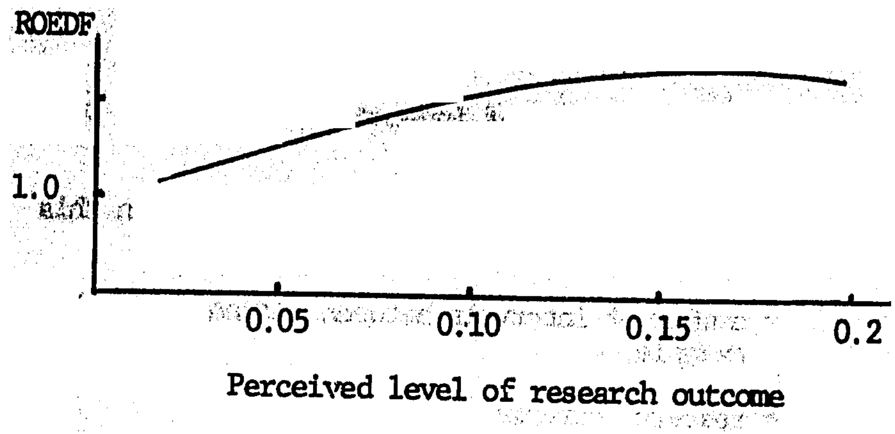

Figure 5.5. Weight given to research outcome to compute diffusion parameter (DDF) (hypothetical).

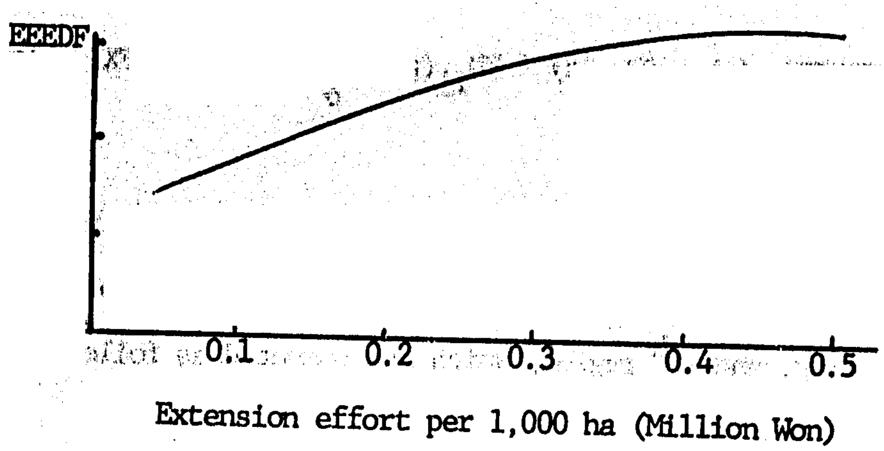

Figure 5.6. Weight given to extension effort to compute diffusion parameter (DDF) (hypothetical).

5.6 ROEDF(I,J,K) = TABLIE [VADF6, SMALL, DIFDF6, KDF6, RYDIFF (I,J,K)]

Where:

VADF6 = function value

SMALL = smallest value of independent variables, in this example, zero.

DIFDF6 = difference between adjacent elements, in this example, 0.05

KDF6 = number of intervals between elements, in this example, 4

$RYDIFF_{ijk}$ = research outcome

We were not very specific as to how the long-run profitability and change in profitability, crop size and regional specialization are computed. All these variables are computed in subroutine TEMP. The long-run profitability is defined as:

$$5.7 \quad PROFTY_{ij}(t) = PD_{ij}(t) * YD_{ij}(t) - \sum_{o} PXD_{il}(t) * FXD_{ijl}(t)$$

Where:

PD_{ij}, PXD_{ij}, YD_{ij} and FXD_{ijl} are, respectively, distributed lag product prices, factors prices, yields, and factor demand for the ℓ^{th} factor, j^{th} crop, and i^{th} region, which are computed as follows:

$$5.8 \quad D * \frac{dPD_{ij}(t)}{dt} + PD_{ij}(t) = PAVG_{ij}(t)$$

$$5.9 \quad D * \frac{dPXD_{i\ell}(t)}{dt} + PXD_{i\ell}(t) = PX_{i\ell}(t)$$

$$5.10 \quad D * \frac{dYD_{ij}(t)}{dt} + YD_{ij}(t) = YLD_{ij}(t)$$

$$5.11 \quad D * \frac{dFXD_{ij\ell}(t)}{dt} + FXD_{ij\ell}(t) = FX_{ij\ell}(t)$$

where: $PAVG_{ij}$, PX_{i1}, YLD_{ij}, and $FX_{ij\ell}$ are respective unlagged current variables, and D is average expected delay on adjustment. We will come back to the computation of these variables later in connection with subroutine FDYLD.

Crop size (SZC) is defined as proportion of total land area allocated to each crop, that is:

$$5.12 \quad SZC_{ij}(t) = A_{ij}(t)/TLAND_i(t)$$

Where:

A_{ij} = Area allocated to each crop in each region, which will be determined by the farm resources allocation component of the KASS model. Until this model is linked with the programming model, the acreage allocation adopted by the initial version of the KASS will be sustained (these corresponding to Policy Alternative II).

TLAND = paddy plus upland in region.

Alternatively, crop size could be defined as the ratio of area to cultivated total land. If land is cultivated only once in a year, both methods will come up with the same figure. If all regions cultivate land equally intensively, there would be no difficulty in comparing intensity among the regions. Where the latter definition is used, rice in Region 2, where rice is more important in absolute as well as relative terms than in other regions, has a ratio indicating it is not important. The same conclusion is applicable in computing the regional specialization index, RSP. This variable is computed:

$$5.13 \quad RSP_{ij}(t) = SZC_{ij}(t)/[ASOR_j(t)/STAND(t)]$$

Where:

$$ASOR_j(t) = \sum_{i=1}^{3} A_{ij}(t) \text{ and } STAND(t) = \sum_{i=1}^{3} TLAND_i(t)$$

As mentioned before, the distributed lagged extension budget is used for computing the weight needed to construct the parameter, DDF. That is:

$$5.14 \quad D * \frac{dBEXD_{ij}(t)}{dt} + BEXD_{ij}(t) = BEXLJ_{ij}(t)$$

Where:

$BEXLJ_{ij}$ = the unlagged extension budget for each crop in each region per unit of land, and D is average expected delay to adjust.

How does government allocate total extension budget over crops and regions? First, we assume that total extension budget of the central government (GBEX(t)) is growing at a constant rate; that is:

$$5.15 \quad GBEX(t) = (1.0 + GGBEX * T) * GBEXI$$

Where:

GGBEX = the rate of growth of budget

GBEXI = initial total extension budget

Then, this total budget is hypothesized to be allocated over regions as follows:

$$5.16 \quad BEX_i(t) = \left[\frac{BEXA*TA_i(t)}{STA(t)} + \frac{BEXB*TLAND_i(t)}{STLAND(t)}\right] *GBEX(t)$$

Where:

BEX_i = regional total extension budget

TA_i = total cultivated land in each region

STA = sum of cultivated land over regional or national total cultivated land

$TLAND_i$ = total agricultural land in each region

STLAND = sum of total land over regions or total agricultural land

BEXA and BEXB = parameters

Then, to guide regional extension budget allocation to each crop, the following score system is used:

$$5.17 \quad SCORE_{ij}(t) = SCOR1 * PFEDF_{ij}(t) + SCOR2 * PCEDF_{ij}(t) \\ SCOR3 * CSEDF_{ij}(t) + SCOR4 * RSEDF_{ij}(t) + \\ PSCORE_{ij}(t)$$

Where: PFEDF, PCEDF, CSEDF and RSEDF are the weights used to compute the parameter DDF, as seen before. $PSCORE_{ij}$ is a policy-determined score given to each crop to implement a certain policy in support of export or attainment of necessary food grain production. SCOR1,2,3,4 are the respective weights given to individual factors in the equation. Extension budget for individual crop per unit of land is hypothesized to be allocated as follows:

$$5.18 \quad BEXLJ_{ij}(t) = \frac{SCORE_{ij}(t)}{SSCORE_i(t)} * \frac{BEX_i(t)}{TA_i(t)}$$

Where:

$$SSCORE_i(t) = \sum_{j=1}^{13} SCORE_{ij}(t)$$

BEX_i = regional total extension budget

TA_i = sum of total cultivated land in each region

Now that we have learned how the parameter $DDF_{ijk}(t)$ is computed, let us examine the role this parameter plays in determining the length of delay (DGA), the dropout rate (RRF) and the input rate (EDF). The length of delay, DGA, is computed once at the beginning of a year, when every new research outcome is ready to be extended. Then this value is carried over until that research outcome is completely disseminated. This is done mainly because the DELDT subroutine is not capable of the time-varying delay.

5.19 $DGA_{ijk}(t) = \text{MAX}\ [1.0,\ (DGAM - DDF_{ijk}(t))]$

Where DGAM is a parameter given that reflects a maximum delay in year in the worst case.

Note that as the parameter, DDF, increases, the length of delay is shortened but restricted to a minimum of one year. Also, note that the length of delay or expected average delay represented by DGA has a different notion from that often used by the sociologist. The expected average delay used by the sociologist in adopter distribution is the weighted average time between initiation and completion of an innovation adoption for a whole population. But, the expected delay used, here, DGA, is changing with time and corresponds to the adoption delay of each year's input rate (EDF).

It is possible to construct a model of what the sociologist talks about, however. The only modification from the one we constructed is to treat the input rate as an impulse composed of the whole population. That is, the whole population is assumed to be an adopter candidate from the beginning, instead of assuming a fraction of the population are candidates in each year.

Similarly, the dropout rate, RRF, is defined as:

$$5.20 \quad RRF_{ijk}(t) = MAX\ [0.0,\ (RRFM - RRFA * DDF_{ijk}(t))]$$

Where:

RRFM = maximum dropout rate

RRFA = parameter to conver DDF into a suitable magnitude

As DDF increases, the dropout rate (RRF) decreases, but remains non-negative. Another type of restriction is given to this rate, too. Where the modern plus transitional land become more than 80 percent, the dropout rate (RRF) is equal to zero.

In determining the input rate, EDF, we put what Manetsch and his associates call input rates due to promotion and due to diffusion together to form one category. Thus, we have only one delay process in our model instead of one for promotion and another for diffusion. If the expected average adoption time, here termed DGA, and adopter distribution parameter, KGA, are not different in both delay processes, we can consolidate them into one process without much loss. In addition, we assume that both the modern land (AMP) and transitional land (TSP) have demonstration or diffusion effect, the latter having somehow less effectiveness than the former. The input rate for each research outcome for each crop, region and point in time is defined as:

$$5.21 \quad EDF_{ijk}(t) = AEE_{ijk}(t) * TDP_{ijk}(t) + AMT_{ijk}(t) * AMP_{ijk}(t) + DFC * AMT_{ijk}(t) * TSP_{ijk}(t)$$

Where:

TDP_{ijk} = traditional land

AMP_{ijk} = modern land

TSP_{ijk} = transition land

DFC = a parameter

5.22 $AEE_{ijk}(t) = AEEA * DDF_{ijk}(t)$

5.23 $AMT_{ijk}(t) = AMTA * DDF_{ijk}(t)$

Where AEEA and AMTA are again parameters. Thus, the first term in Equation 5.21 is the input rate due to promotion, and therefore AEE is a fraction indicating what percent of the traditional land is going to enter the delay process per year. The next two terms in the same equation correspond to the input rate due to demonstration or diffusion from noncommunicative information sources. Thus, the variable (AMT) is a kind of multiplier indicating how many farmers a modern farm or transitional farm can try the new technology. Now two conditional restrictions are imposed on the input rate (EDF). The first is a logical restriction: the input cannot exceed the traditional land:

5.24 $EDF_{ijk}(t) = \text{Min}\ [EDF_{ijk}(t),\ TDP_{ijk}(t)]$

EDF in the right side of the equation is the input rate computed in Equation 5.21. The other restriction is that whenever modern land (AMP) plus transitional land (TSP) exceeds 80 percent of total land population, we let the input rate, EDF, equal the traditional land TDP. That is:

5.25 $EDF_{ijk}(t) = TDP_{ijk}(t)$

The reason was explained earlier in the discussion of the restriction on the dropout rate, RRF.

This is the essential overall picture of our social diffusion model. Before discussing how average productivity changes due to innovation diffusion, we add two more points. First, now that we explained how the dropout rate (RRF) is determined, we modify the definition of the modern land (AMP) given in Equation 5.3. The correct one actually used is:

$$5.26 \quad AMP_{ijk}(t) = AMP_{ijk}(t) + \int_0^t AR_{ijk}(t) * [1.0 - RRF_{ijk}(t)]\, dt$$

The reader may wonder about the other delay subroutine, such as DELVF, which can directly count the loss rate, which is equivalent to the dropout rate (RRF). The reasons are: (1) to demonstrate the usage of different delay subroutines, and (2) to make the dropout or loss rates functions of time.

The second modification involves the definition of the land. The population can be defined in terms of number of farmers or acreage, and in absolute or relative terms. In this model any population is specified in terms of percent of land. In other words, the initial value of the traditional land (TDP) for any campaign of the research outcome adoption is set equal to 100, which is total land appearing in Equation 5.4, termed TTP. What the modern or transitional land (AMP or TSP) shows is what percentage of land allocated to a specific crop has adopted or is trying a certain new technology. There are two basic reasons for adopting this definition. First, it prevents additional complexity. Second, even if we use the absolute acreage, we still have to convert it to relative terms in order to compute average productivity gains.

In connection with this definition, an additional assumption is necessary. The area allocated to a specific crop changes over time, either due to economic adjustment or the fact that some agricultural land transfers to nonagricultural usage. Is the more modern or traditional land likely to transfer to the other crop or nonagricultural usage? The expected change in area response is small, owing to assumptions made either in the initial version of the KASS model or in the farm resource allocation component, we can generally assume that the conversion of cropland will be the same for modern and traditional land.

It seems appropriate to specify one more implicit model assumption. We assumed a maximum of five successive campaigns for a crop during the planning horizon. Would it be more realistic to assume that only the farmer who have adopted the first campaign are eligible for the second, only those who have adopted the second campaign are eligible for the third, and so on? This is not necessarily realistic. Furthermore, there is a time lag between successive research outcomes. Therefore, if we were to adopt this restrictive assumption, it might not correspond to reality. In addition, there is no apparent reason that a farmer cannot adopt the new technologies in a different order. This is one of the critical model assumptions.

Now that we have specified the necessary model structure and assumptions about the social diffusion of an innovation in detail, we are ready to present a method for computing the expected average productivity gain. Individual research outcomes having a set of perceived attributes (RYDIFF) have been defined as productivity gain in terms of yield at the experiment station, not at individual farms.

Would the productivity gain at individual farms adopting the new technology be the same as that at the experiment station? It is not hard to imagine that some farmers' resource base or technology, other than that to be disseminated, would be quite similar to the experiment station situation, but many would not. We may well assume that farms with a good resource base or equiped with better knowledge would adopt a new technology first. This argument then implies that as a new technology is disseminated over farms, the productivity gain on individual farms would decline. This conclusion is quite consistent with findings from the green revolution process by many researchers, such as Evenson [E.3], Wharton [W.3], etc.

If we assume there is no difference in other technology or resource bases between the experiment station and individual farms, and that the transitional land will experience the same productivity gains as the modern land does, the expected average productivity gain due to an innovation diffusion in a region will be:

$$5.27 \quad GTZ_{ijk}(t) = RDYIFF_{ijk}(t) * [AMP_{ijk}(t) + TSP_{ijk}(t)]$$

Accumulated productivity gain due to successive innovation diffusion for a crop on a regional basis will be at a given point of time:

$$5.28 \quad GTZS_{ij}(t) = \sum_{k=1}^{k} GTZ_{ijk}(t)$$

What the first equation says is that if the modern land (AMP) plus the transitional land (TSP) turns out 100 percent, the productivity gain on a regional basis will be the same as RYDIFF.

Now let us assume that: (1) the resource base or other technology of individual farmers at their disposal is not the same as that of the experiment station (2) there is some difference in productivity gain, by a factor DFC, between the modern and transition populations, and (3) the productivity gain diminishes as more farmers adopt a new technology. Then the expected average productivity gain due to dissemination of a new technology in a region will be:

$$5.29 \quad GZ_{ijk}(t) = RYDIFF_{ijk}(t) * [1.0 - DF_{ijk}(t)] * [AMP_{ijk}(t) + DFC * TSP_{ijk}(t)]$$

Where DF is an average discounting factor and computed as a function of the modern land (AMP) by using the TABLIE function. Function values are given in Table 5.2.

Table 5.2. Function Value of Discounting Factor, DF (Hypothetical).

	Modern Land (In Percent)					
	0	20	40	60	80	100
DF	0.03	0.03	0.035	0.042	0.51	0.063

The farmers' resource base or other technology changes over time. Thus, to correctly estimate this average discounting factor (DF), the function shifter must be incorporated in one form or another. However, this type of interaction among technology level, input use rate, and the resource base will be considered specifically and incorporated into the product supply and factor demand projection component models in later chapters.

The accumulated productivity gain on a regional basis can be computed easily at a given point of time as:

$$5.30 \quad GZS_{ijk}(t) = \sum_{k=1}^{5} GZ_{ijk}(t)$$

We need to compute the rate of change in productivity gain due to the new technology dissemination. Let us define it as the total factor productivity growth rate and lebel it YZ.

$$5.31 \quad YZ_{ij}(t) = [GZS_{ij}(t) - GZS_{ij}(t-1)] \; [100 + GZS_{ij}(t-1)]$$

Since the gross productivity gain, GZS, is defined in terms of percentage, we must divide the successive difference by 100, plus the previous year's gross productivity gain.

Thus far, innovation diffusion and the resultant productivity gain due to the public investment have been considered in research. Is the public institution the only one where an innovation or a new technology is being generated? It is obvious that some farmers act more or less as innovators in selecting seed, using production factors, or applying husbandry suitable to his specific farm location. Other farmers imitate this progressive farmers. Therefore, indigenous technological change is made available by the leading local farmers themselves. As a matter of fact, this has been the major source of technological changes prior to establishing the modern experiment station. It also seems that this source of technological change is very important even at the present time. It is also a well known fact that the agribusiness firm that supplies the farm sector with modern inputs or processes farm products engages in research and development and disseminates findings to farmers.

The next question is whether the extension worker is the only means of bringing new information from the public research institutes to farmers. The extension worker's job is to facilitate communication between the farmers and the public research institutes, as well as among farmers themselves. This includes finding better practices or husbandry at a farm or location, and introducing them at other farms or locations.

In summary, it is quite possible that some technological change takes place even slowly and is disseminated among farmers or agribusiness firms without the help of public research and extension institutes. It is also true that the extension worker can accelerate the diffusion of this type of indigenous and spontaneous technological change. The productivity gain due to this process is hypothesized as a function of the distributed lag extension budget with a positive intercept, as shown in Table 5.3. Then the function value of the productivity gain for each crop in each region is interpolated by the TABLIE function. Let us term this productivity gain YW. Then total productivity change due to research and extension turns out:

$$5.32 \quad YZD_{ij}(t) = YZ_{ij}(t) + YW_{ij}(t)$$

Table 5.3. Productivity Gain Due to Extension of Spontaneous Technological Change (Hypothetical).

	Extension Budget, Million per 1,000 Ha.					
	0.0	0.04	0.08	0.12	0.16	0.20
Productivity gain	0.0003	0.007	0.01	0.012	0.0138	0.015

In summary, the total factor productivity growth rate (YZD) is the only variable in this subsector model to be transferred to other subsector models discussed in later chapters for the present purpose of the study. The perceived levels of research outcomes (RYDIFF) and the derived total productivity growth rate (YZD) are crucially important variables in our whole model.

The variable RYDIFF is defined as the biological research result in terms of the rate of increase in the yield level at experiment station. The figures for RYDIFF in Table 5.1 do not represent what will occur unconditionally in the future or a target the public sector wants to achieve. Those figures simply represent one set of all possible research outcomes. This does not necessarily mean that this set of research outcomes will be likely to occur. It is simply a point of departure for examining the consequence of some possible research outcomes on the overall performance of the Korean economy. In this sense, the point of departure can be extremely high or low as compared to what will happen in the future.

We need to run an intensive policy experiment on this variable, since the research enterprise involves rather high uncertainty or risk. This policy experiment is intended to provide public decision-makers with: (1) some information on desirable biological research outcomes so they can design and build a research institute to secure these desired levels of research outcomes, and (2) some possible crop-specific strategies to reach some of the agricultural development goals.

In this chapter we have modeled the complex and ill-structured system of biological research and dissemination of its results. The relationships described in this public subsector component are not technical, but mostly socioeconomic ones. These relationships have not been well studied thus far. The model presented here is based more on art than science. This is one way to model a complex but ill-structured system. The basis of constructing this kind of model is: (1) related theories and (2) experiences of experts in this field, since "if experienced observers believe that is the way things really work, that is the way they should be in the model, even if the parameters cannot be measured" [Kresge (K.8)]. What is needed for improving this component are: (1) in addition to further testing and refinement of model structure, data gaps should be filled with more knowledgeable estimates from researchers, extension workers and other informed personnel, and (2) based on more reliable data and structure, many additional computer runs should be made for the purpose of detecting possible errors and further model validation.

CHAPTER VI

PRODUCTION FUNCTION AND PRODUCT SUPPLY PROJECTION

This chapter proposes a form of production function that has a dynamic long-run property and is used to project yields per land unit for 13 crops or crop groups in each region. First, we review some of the supply response studies and projection techniques used for product supply in section one. The mathematical model is discussed in two sections. The second section discusses the projection model for annual crops. Then, in section three a yield projection model for perennial crops, fruit and mulberry-silk is developed. Lastly, in section four, we discuss the sources of data and parameter estimation problems.

Agricultural Supply Studies in Literature

The study on agricultural supply of either aggregate study or an individual crop is a relatively rich part of agricultural economics literature. Historically, product supply studies have revolved largely around hypotheses that either farmers are not price responsive and lack profit motivation or that agricultural supply functions have elasticities near zero.

We do not intend to intensively review studies, models or explanations accounting for agriculture's failure to contract or to expand output. In fact, Heady [H.11, p. 675-676] and Hathaway

[H.5, Ch. 4], among others, summarize the hypothesis concerning this matter. On the other hand, Johnson [J.16, Ch. 3] has reviewed some of the main explanations of agriculture's historic failure to contract or expand output, in order to advance a new hypothesis involving investment and disinvestment or the lack thereof as determinants of supply response.

The product supply function can be derived from the static neoclassical economic theory, which is normative as it assumes maximizing behavior of producers and consumers. Assuming diminishing returns to scale with some fixed assets, the marginal cost curve derived from production function having the above nature is interpreted as the short-run supply function of the firm. Based on this theory, implied estimation function of the supply has a form:

$$S = f(P_y)$$

Where S is supply and P_y is product price. This form assumes first of all that input prices are fixed, which is certainly not the case in the real world. With input prices as the supply function shifter, the estimation form is:

$$S = f(P_y, P_{x_1})$$

Where P_{x_1} stands for the relevant input price. Even in this formulation the estimation function oversimplifies the real world. That is, any firm has limited amounts of resources and usually produces more than one product With this consideration, the supply function is specified:

$$S = f(P_y, P_{x_i}, P_{a_i})$$

Where P_{a_i} stands for the relevant price of alternative product

Thus far, we have implicitly assumed current prices would influence current supply by affecting yeilds. As Fox [F.9] discusses, in general, the quantity of a crop ready for harvesting is determined by economic factors that operated before planting time and during growth stages in which yield-influencing practices or materials may have been applied, and by noneconomic factors such as weather. The logical implication of this argument is that prices used as independent variable in supply estimates should include at least one year lagged ones with or without current ones.

It seems that most supply studies prior to the 1950s were based on the above lines of thinking.[1] Nerlove views supply response as an adaptation process in an uncertain world where lags in the adjustment processes exist. Because of uncertainty and sticky adjustment processes, he assumes farmers' adjustments do not take place instantaneously in the aggregate, since farmer's expectations and lags differ. The basic element of the Nerlovian dynamic system can be summarized as follows [See, Nerlove (N.6, p. 53-63)]:

$$S_t - S_{t-1} = \gamma[S_t^* - S_{t-1}]$$

Where S_t stands for the current or actual output, S_t^* for long-run equilibrium or desired output, and S_{t-1} for one year lagged actual

---

[1]For a review of supply function studies, see Nerlove [N.6, Ch. 3] and Knight [K.6].

output. The desired output can be expressed as a function of farmer's expectation on future price (P_t^*) such as:

$$S_t^* = a + B\ P_t^*$$

In turn, this expected price can be expressed:

$$P_t - P_{t-1}^* = \partial[P_{t-1} - P_{t-1}^*].$$

Where P_{t-1}^* and P_{t-1} are, respectively, one year lagged expected and actual price. γ and ∂ are called the respective elasticity or coefficient of adjustment, depending on whether output or price is expressed in logarithmic or absolute terms.

These three equations are derived from Nerlove's basic system of dynamics. Let us interpret this system. First of all, it is a differential equation system with a numerical solution. That is, the first equation, for example, can be written:

$$\frac{D \cdot dS_t}{dt} + S_t = S_t^*$$

Where D stands for the expected average years of adjustment of the actual supply to the desired one. Euler's numerical solution to above equation is:

$$S_t = S_{t-1} + DT/D\ [S_t^* - S_{t-1}]$$

which is exactly the same as the first equation of the Nerlovian system after noting that DT is a time increment, and DT/D has the same meaning as γ. Secondly, in this system, the actual output is adjusted or respond to the desired or long-run equilibrium. What would this mean? There seem to be few theoretical problems in this formulation as it contains little thoery. Nerlove's work has stimulated much subsequent research on supply or factor demand estimates. However, this does not necessarily mean that this formulation explains the farmer's actual supply response very well. We will now examine what is needed for more realistic supply prediction.

First, a personal comment. Nerlove and all his subsequent followers assume, almost without making specific comment or criticism, that the repercussion of a disturbance over farmers' reaction is represented by a simple exponential function, as modeled by the first-order differential equation. Do they do this for simplicity or because they believe their assumption is realistic? What are the empirical implications for the innovation adoption process modeled with S or J shaped response curve? Would supply response studies be improved by modeling with a higher-order differential equation rather than with the first-order differential equation?

The second comment has to do with forces determining the "adjustment coefficient." Nerlove [N.7] makes it clear that the estimated adjustment coefficient is unstable over time. What forces change this coefficient? Does this involve investment and disinvestment behavior based on direction, duration and magnitutde of price change?

At around the same time, Nerlove advanced the pioneering technique of estimating supply responses, there was some theoretical advance in understanding farmers' response. This has to do with the asset fixity theory involving investment and disinvestment due to Johnson and his associates [J.4, J.5, J.13, J.16, B.13, E.1]. This theory and the theory concerning the knowledge situation are the major components used to modify the neoclassical economics. The modification or extension of static theory in this direction intends to explain the phenomena of chronic disequilibrium in the U.S. agriculture more precisely.

According to Johnson [J.16, p. 24],

> "At least three different lines of reasoning have some importance as explanations of the tendency of American agriculture to expand but not contract production. The first and most important of these deals with technical advance. The second deals with improvements in the human agent. The third has to do with the role that various economic adjustments, mainly specialization, play in increasing productivity."

Having felt these explanations to be inadequate, he [J.16, p. 26] concludes that

> "A substantial gain in explanatory power is achieved when the neoclassical analysis is modified: (1) to recognize explicitly that acquisition costs may be less than, or equal to, or less than zero; (2) to recognize imperfect knowledge (as D. Gale Johnson did) of the technology, education, and other changes. . ."

The key concept of the resource fixity theory is the distinction between acquisition price and salvage value of resource, which the neoclassical economic theory fails to make consistently. Then the definition of the resource fixity is as follows:

> "An asset will be defined, very simply and curdely, as fixed ('if it ain't worth varying'). More elegantly stated, an asset will be defined as fixed so long as its marginal value productivity in its present use neither justifies acquisition of more of it or its disposition" [Johnson and Hardin (J.17)].

The same definition can be stated in mathematical form:

$$\infty \geq P_{xa} > MVP > P_{xs} \gtrless 0$$

where P_{xa} stands for the acquisition price of an asset, P_{xs} for its salvage value, and MVP for the marginal value productivity of its present use. Compare this definition with the corresponding implication of the conventional definition of the fixed resource in the short run, which can be defined:

$$\infty = P_{xa} > MVP > P_{xs} = 0$$

What, then, would implication of this theory be in terms of yield, farm organization and production response, and aggregate supply? Since many papers [J.16, Ch. 3 and Appendix, E.1, J.4, J.5, H.5, Ch. 4, and V.3, Chs. 6 and 7] deal with this subject matter in detail, we briefly introduce here the basic idea as in the context of the present study. Suppose a firm producing a product where one factor is variable, such as fertilizer, and the other is fixed. Further suppose that the present farm organization is represented by P_1, Q_1 in Figure 6.1. Assume that the product price has increased to P_2. In this situation, more of the variable input will be used. How about the fixed input, then? There are two possibilities: (1) the MVP of the fixed input may still be low as compared to its acquisition cost, and (2) the MVP is sufficiently increased to justify the purchase of an additional unit of the asset.

Let us assume the first case. Then supply quantity will be increased slightly, such as to Q_2, since one resource is fixed so that production is subject to diminishing returns. Now, suppose the product price has increased to P_3. Then, without doubt, the use of the variable input will be increased. For the fixed asset, one of the two alternatives discussed above will come up again. But let us assume that this much price increase now justifies the additional use of the fixed input. Hence, the production function shifts to the other subfunction.

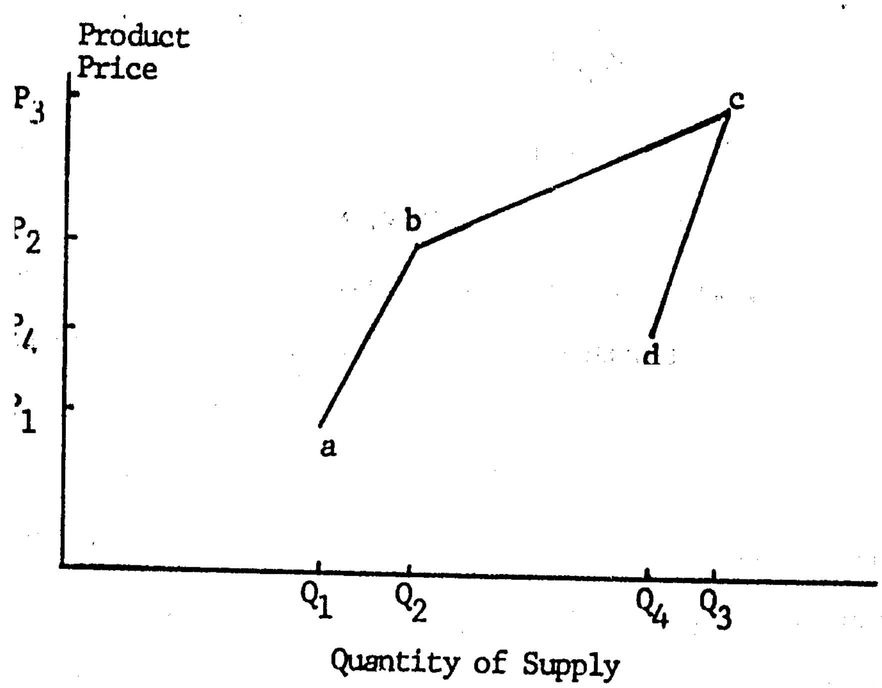

Figure 6.1. Hypothetical supply function derived from resource fixity theory.

In the first case of price increase, only one input was variable, whereas in the second case, both inputs are variable and supply quantity is much increased, such as to Q_3. Thus, the segment of the supply function is more or less flatter than that of the first price increase, as shown in Figure 6.1.

Now suppose the price has dropped to P_4. What might happen to the fixed resource? It is certain that the MVP of this asset is accordingly dropped. Had its salvage value been equal to its acquisition price, the farm would not face a capital loss by liquidating some of this resource so that its MVP would be equal to its market price. However, its MVP may be greater than its salvage value but less than its acquisition cost. If this is the case, the previously acquired full amount of this resource will be still used on the farm. Thus, the supply quantity is now slightly decreased such as to Q_4. Note that the consequence of the definition of the asset fixity yields a partially irreversible and kinked (at Point b) or discontineous supply function. The important conclusion is that the price elasticity of the aggregate supply is different, depending on the direction, duration, magnitude and recent history of price movement.

Smith [S.13] is the first research to consider two prices, acquisition and salvage, for farm-produced inputs in a linear programming model in order to examine the nature of farm organization. This methodology can also be used to determine the optimum investment and disinvestment for any durable inputs. For example, Lee [L.5] applies a different wage rate for disposing of own family labor from that for hiring labor.

More significant application of this resource fixity theory can be found in the supply study. It seems that Halvorson [H.3] is the first researcher to study the impact of the direction of price change on supply elasticity estimation (milk), although Johnson [J.4] and Boyen and Johnson [B.13] have tested this possibility with time series and cross-sectional data, respectively. Later, Barker [B.1] tested the supply theory hypothesis that the elasticity of expansion under rising prices exceeds the elasticity of contraction under falling prices (for milk). Recently, Tweeten and Quance [T.5] confirmed the same type of hypothesis for aggregate agricultural supply. Quance [Q.1] examines capital gains and losses by means of the resource fixity theory. The resource fixity theory does not imply assymetrical responses to price increases and descreases; instead it implies adjustment to a moving target. Empirical evidence that the response is assymetrical is not contradicted by the theory.

In most applications of this theory in supply parameter estimation, it seems that they pay attention exclusively to the elasticity in terms of the direction of price change. That is, it appears that there is no empirical study to test the hypothesis that the elasticity is also different, depending on the duration and magnitude of price change as implied by the theory. In other words, they have studied the segment of a study curve such as bc and cd in Figure 6.1, but not segments ab and bc where a kink occurs. This kink may not be observable in the aggregate data, whereas Figure 6.1 is drawn on the basis of a firm. This is, perhaps, an important reason that they have not studied this kink in deriving supply estimates for the aggregate data. In fact, the supply function of each individual firm may be kinked at different levels of supply quantity, or the price expectation may be different from each other.

Many problems are involved in the analysis of agricultural supply. Heady [H.13] and Nerlove [N.7] discuss these difficulties or problem areas. The common factors can be summarized as those concerning: (1) complexity of production system, (2) technological change, (3) aggregation, (4) fixed or quasi-fixed production factors and (5) uncertainty.

Learn and Cochrane [L.3] conclude that "regression analysis of time-series data is an imperfect tool for supply analysis where structural changes have occurred during the time period analyzed. . .Regression analysis has rarely provided satisfactory supply estimates in the past. . ." Staniforth and Diesslin [S.15] conclude that

> "The major single limitation is that it (regression analysis) cannot be used for prediction in light of new variables and structures. Regression models. . .reflect historic relationships and at best describe present relationships. . .prediction is more important than the record of the past."

As we have noticed, technological or structural change which is one important supply function shifter among subfunctions as defined by Learn and Cochrane [L.3] plays an important role in economic development or adjustment process in agriculture.

Dean and Heady [D.5] hypothesize that technological change affects supply elasticity itself. How should we handle this important variable in modeling the supply system? Many seem to consider this variable in supply estimation as they do in aggregate production function estimates. However, none of them can be considered adequate. Bonnen and Cromarty [B.11] put it this way:

> "For the technology and weather variables the data used are inadequate but are better than complete omission or oversimplification which accompanies the use of a linear time trend."

Johnson [J.8] suggests that

> "A principal problem encountered in synthesizing macro supply estimates from micro data has to do with predicting which inputs or resources are changed and which are not changed. . .Changes in inputs to be considered include, of course, those necessary in introducing new technologies, and securing the benefits of regional, sector and farm by farm specialization and diversification."

Inherent limitations of regression models in predicting the supply quantity seem to have caused research workers to turn to budgeting, programming, production function or related techniques. It is not possible to review here all relevant supply studies based on these techniques, however.[2] In fact, the production function is the foundation of supply. Once the production function is specified, it is easy to handle supply problems and factor demand. Indeed, Wipe and Bawden [W.4] derive firm-level supply equations from empirically estimated production functions to predict firm output and estimate supply elasticities. After making a comparison with the actual data, they conclude that derived supply equations are not empirically reliable. That is, they find that predictions ranged from slight underestimates to extreme overestimates of actual output, with the latter being most prevalent. Derived supply elasticities were generally found higher than those obtained by direct regression analysis. This conclusion does not seem new in literature, however. This author [L.4] has also discussed these properties of derived supply function. The degree of disagreement between actual response and response derived from the production function would become even greater when the Cobb-Douglas form of production function is used as by Wipe and Bawden.

What are the possible causes of this general overestimate and inconsistency of estimates or predictions they find? A critical factor

---

[2] For basic methodologies, see Heady and Dillon [H.18] , and Heady and Tweeten [H.19] for production function approach; Heady and Candler [H.16] and Day [D.3] for programming approach; and Johnson [J.8] and Mighell and Black [M.16] for budget approach.

is that the farmer is not a straightforward profit maximizer. He has a much more complex set of variables to consider than that dictated by the static micro economic theory. He has a set of restrictions in making production decisions. That is, he has limited amount of capital, takes uncertainty into account, does not respond to change instantly, etc. In addition, the production parameters may not remain stable over time. We must consider all relevant decision environments of farmers if we are to make a realistic prediction, especially when we adopt a production function approach.

We want to close this subsection by quoting Heady [H.13]:

> "The efficiency of either (positive and normative) thus depends on whether the relevant variables are included and accurately measured in the empirical model and how well they correspond with the real world conditions as they will exist during the period for which predictions are to be made."

Before moving into the next subsection, it seems worthwhile to briefly discuss literatures concerning supply studies in the LDCs. It appears that the marketed surplus model of the subsistence crop developed by Krishna [K.9] is the first supply model unique to LDCs. What is new is that the price elasticity of supply in this model is indirectly estimated, since the standard technique is difficult to apply due to a lack of data.

On the other hand, after criticizing the weakness of Krishna's model in terms of assumptions made, Behrman [B.5] advances a new model of the marketed surplus of the subsistence crop, which is essentially an extension of Krishna's model. According to Behrman,

> "Some economists contend that the supply response of the agricultural sector in less-developed countries is quite similar to the response in countries with high per capita income. Others argue that this response is perverse in the sense that increased prices result in smaller quantities.

> "A third group maintains that institutional constraints are so limiting that no significant response to economic incentives is likely to be observed."

His own position is that,

> "To some degree, these different opinions have resulted from the failure to distinguish explicitly between the supply of a single crop and the supply of all crops, between total production and the marketed surplus, and between short-run and long-run responses."

He then estimates acreage response elasticity of the subsistence crop to price change. In fact, what we need to know in the context of development is not acreage response, but the supply of total crop production and yields. We know acreage responses to price change reasonably well, but what is less well known is whether or not total production and yield respond to economic opportunities.

Schultz [S.2, p. 37] hypothesizes that, "There are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture." Nevertheless, they are poor, not because of malallocation of resources but because of the low-level equilibrium trap. In fact, Schultz's hypothesis is intended to derive a proportion that the reorganization of the existing resources at the farmers' disposal may not serve to increase total production.

Now, let us turn to methodologies they used to make production projection. One of the conclusions described above was that neither classical supply studies nor orthodoxical production function studies are adequate for making projection of product yield. This may be equivalent to saying that there is no established methodology that can be used for varying situations. Perhaps for this reason, they formerly used quite diverse varieties of methods. For example, Blakeslee, et al. [B.9] used extrapolation of the past trend of yield in projecting world food production, demand and trade.

The same technique was used by Desaeyere, et al. [D.9] in making a long-term projection of supply and demand for Belgium agriculture. As everybody knows, the trend does not have much meaning. Rather, this technique disguises some important economic relationships. Black and Bonnen [B.8] base their supply projection on some judgment as to what the impact would be if technology made available by experimental stations is adopted. Johnson [J.12] claims this methodology works out well and names this type of projection as the traditional projection in the sense that it is not computerized. Bonnen [B.10] reviews several projection studies and tests the accuracy against real world data. One of his conclusions is that the projection is underestimated, because they do not consider some aspects of economic adjustment, such as regional specialization.

Tom [T.4] discusses steps in economic projection. After adding several difficulties with production projection, such as the fact that annual crop production in Northern Nigeria varies up to 40 percent, which is attributed mainly to climatic factors and irresponsiveness of subsistence farming, he introduces the methodology of yield projection used for Nigeria. According to him, the factors considered are improved husbandry and equipment, improved seed, seed dressing, and insecticide in storage. He does not indicate what adjustments the farmer makes to adopt technology, possibly due to space limitation. However, it is hoped that this plan is not the type of plan Dandekar [D.2] criticizes.

In addition, Tom briefly introduces the National Council of Applied Economic Research's projection methodology used for India, one of the few comprehensive studies of agricultural supply in a developing country, which will be reviewed here in detail.

The National Council of Applied Economic Research [N.2] presents projections of demand for and supply of agricultural commodities for India (1960-61 and 1975-76). The basic method used in projecting production or potential supply can be best explained by a diagram, as shown in Figure 6.2. First, they project areas with or without irrigation facilities and then improved seed.

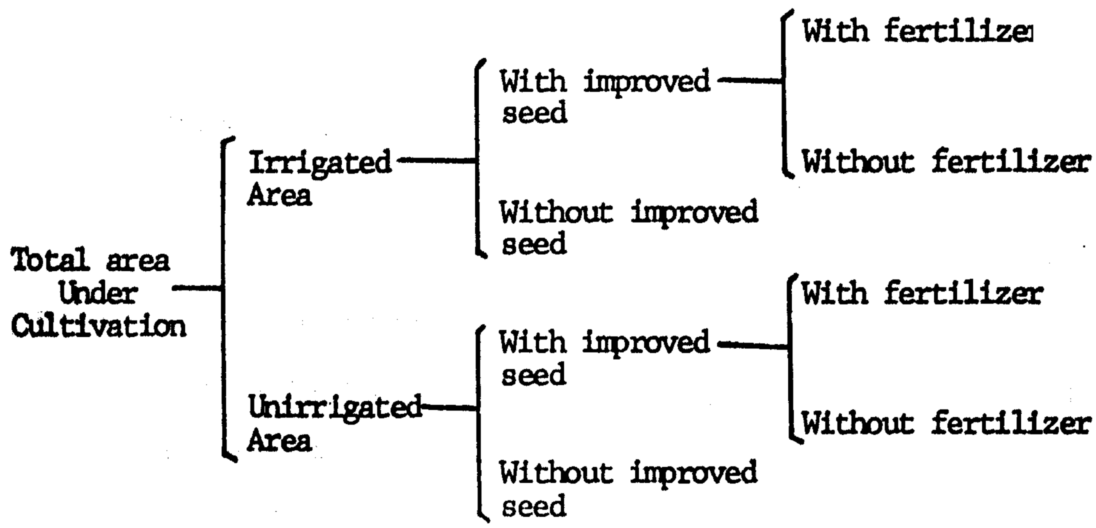

Figure 6.2. Cultivated land classification by technology for Indian agriculture. Source: National Council of Applied Economic Research [N.2, p. 159].

Then it is assumed that land with improved seed is entitled to be cultivated with fertilizer. Basically there are six different lands for each crop. This type of land classification is based on the availabilities of the various inputs considered. Next, they determine yield response for each of the various land categories from various sources of data. Once areas and corresponding yield rates are known, it is very simple to compute total production or average yield.

There are some interesting features in this study. First, they take into account the effects of what they call intangible factors, which include community development programs, credit facilities and marketing, agrarian reforms and improved agricultural practices. However, it is not very clear how these intangible factors affect production. The other point is that they claim that the production level obtained represents the potential, and the actual production will be adjusted by whether or not pesticide is used.

Cownies, et al. [C.9] presents a slightly different model for projecting production for West Pakistan. In their scheme for land classification, the with-or-without-fertilizer category is dropped from that done by the National Council of Applied Economic Research, or from Figure 6.1. Instead, they assume that yield in each of the four land categories is:

$$Y_i(t) = Y_i(o) + n_i \; [f(t) - f(o)]$$

Where $Y_i(o)$ and $f(o)$ are, respectively, the yield and fertilizer application rate in the base year, whereas $Y_i(t)$ and $f(t)$ are, respectively, the corresponding current rate, and n_i is fertilizer response coefficient.

Both models base their projection on several highly subjective assumptions. No economic basis is given in allocating resources among crops. The yield level is assumed to be a linear function of only fertilizer application. Variable input levels are treated as exogenous. Farmers are assumed to have no ability to adjust to changes in economic variables.

A similar model is used by Lele and Mellor [L.15], not for making projection, but for identifying the source of productivity charge in food grain for India. They use historical input and output levels determined by farmers.

The national Council of Applied Economics Research model does not seem to be worked out well. The result of the model projection shows that India would attain self-sufficiency in food grains by 1964, and then would have over production. But nobody insists that India has achieved food self-sufficiency at the present time. Either projection of demand or production or both must be considered unrealized, even in approximation. This kind of projection or planning model seems to invite a criticism, such as that given by Dandekar [D.2]. Let us quote again what he says:

> "A plan is a plan in the true sense of the term only when it is a proposal for action on the part of the one who makes it. The reasons our plans in agricultural development have not been plans in the true sense is that they have not been essentially plans for state action."

It is obvious that making the farmer's resources allocation or related decisions is not a job that can be done directly by a state.

In summary, there seems to be no established methodology that we can directly apply to projecting yields over time. Thus, in the following section we propose computerized methodology that allows various economic factors to play a role in determining yield levels.

Yield Projection Model for Annual Crop

A change in production level and hence supply must be interpreted as a consequence of either a change in the rate of the so-called conventional input used, a change in the technology level or a change in random disturbance factor such as weather. The supply function most commonly used is expressed as a function of the product price or combined with factor prices, with or without other variables. This is incorrect formulation. The price change influences product supply indirectly through forcing a change in input use.

Johnson [J.5] points to the heart of the weakness of this pragmatic formulation by saying:

> "One of the more serious difficulties faced by the commodity supply analyst is the lack of data on the amounts of different resources used in the production of each farm product. Lack of such data requires researchers to deal with price-output rather than with production function relationships, thus limiting their alternative approaches."

We reject here the price-output relationship approach. Instead, we adopt what might be called an economic system approach capable of modeling the effect of change in input used as well as change in technology. The model must also be capable of dealing with dynamic aspects of agricultural economic systems.

The production function used here is not a sort of aggregate production function disembodied technological change. The term "technological change" used in this sort of aggregate production function is, according to Schultz [S.2, p. 137], "not an analytical concept for explaining economic growth." This is so because, according to him, "To use it for this purpose is a confession of ignorance, because it is only a name for a set of unexplained residuals." A number of authors agree that to measure technological change in that way is a "measurement of our ignorance."

One of the main purposes of studying an aggregate production function is to provide a basis for prescribing policy alternatives designed to affect the growth rate. According to Denison [D.8], this is equivalent to a "menu of choices available to increase the growth rate." The menus provided by the aggregate production function studies, including the Denison work itself, do not seem very precise inasmuch as the policy-maker can widely select an appropriate set of policy measures without confusion or ambiguity when applied to the agricultural sector.

To identify more precise sources of the growth or yield function shifters in order to provide a more precise menu of policy choice and to provide a framework of structural analysis of an economic system, we propose an aggregate production function:[3]

$$6.1 \quad Y_{ij}(t) = A_{ij} \, \pi \, X_{ij\ell}^{a_{ij\ell}(t)}(t) \, \pi \, Z_{ik}^{b_{ijk}(t)}(t)$$

which is essentially a Cobb-Douglas-type production function, and where:

Y_{ij} = production per unit of land yield of j^{th} crop in i^{th} region

$X_{ij\ell}$ = ℓ^{th} the so-called conventional production factor for producing j^{th} crop in i^{th} region

Z_{ik} = k^{th} the so-called conventional production factor or what we call technological or structural change variable in i^{th} region

A_{ij} = $a_{ij\ell}$ and b_{ijk} are appropriate production parameters.

---

[3]Notation used for variables or parameters here are not the same as those used in computer programs just for the simplification. However, we will specify the notation used in computer program at appropriate places for major variables.

The yield function given in Equation 6.1 does not seem much different from aggregate production function or micro firm production function often used. First, this yield function has the property that the source of the growth or technological change are disaggregated in detail. Second, this yield function has a property of a long-run context in the sense that all production factors are identified. Third, all independent variables (X_{ijk} and Z_{jk}) are endogeneously determined, based on various economic variables or public policies, projects or programs.

To simplify the model, we adopt Taylor's expansion series of the production function in Equation 6.1 [see, Allen (A.8, p. 457)]. Ignoring the higher-order terms, we have:

$$6.2 \quad Y_{ij}(t) = Y_{ij}(t-1) + \sum_{l} [X_{ijl}(t) - X_{ijl}(t-1) * \frac{\partial Y_{ij}(t-1)}{\partial X_{ijl}(t-1)}$$
$$+ \sum_{k} [Z_{ik}(t) - Z_{ik}(t-1)]* \frac{\partial Y_{ij}(t-1)}{\partial Z_{ik}(t-1)}$$

By rearranging, we have:

$$6.3 \quad Y_{ij}(t) = [1 + \sum_{\ell} a_{ij\ell}(t-1)) * \frac{\dot{X}_{ij\ell}(t)}{X_{ij\ell}(t-1)} + \sum_{k} b_{ijk}$$
$$\frac{\dot{Z}_{ik}(t)}{Z_{ij}(t-1)}] * Y_{ij}(t-1)$$

Where: $\dot{X}_{ij\ell}(t) = X_{ij\ell}(t) - X_{ij\ell}(t-1)$, and $Z_{ik}(t) = Z_{ik}(t) - Z_{ik}(t-1)$.

Note that the intercept term A_{ij} in Equation 6.1 has disappeared in the manipulation process. In a case of the aggregate production of disembodied technological change, the intercept term (A_{ij}) plays an important role. That is, the term is assumed to be a time-varying variable, and the rate of change in intercept appears in a derived equation, such as Equation 6.3. and is known as total factor productivity growth rate, which is a residual and criticized as a "measurement of ignorance" by Schultz and others.

We assumed the intercept term (A_{ij}) to be time invarient, since we deal with a sort of embodied technological change. That is, we intend to include all possible sources of productivity change, and assume any change to be embodied in one of the production factors considered in the production function.

Also, note that we have treated the production elasticities or productivity coefficients as if they were time invarient. In fact, the productivity coefficients ofthe function shifters, b_{ijk}, are assumed to be time invarient at the model's present stage, with some exceptions, whereas a_{ijl} is time varying. But this variable is very slowly changing over time. For this reason, and to avoid extreme complications, we assumed $a_{ij\ell}$ to be time invarient only in mathematical manipulation to get Equation 6.3.

Equation 6.3 is the final equation used for making yield projections with a minor modification to be explained later. Once the optimum input rates of production factors ($X_{ij\ell}$), which will be discussed in detail in Chapter VII, and the rate of change in structural variables are known, the yield level (Y_{ij}) is ready to be projected.

The structural variables considered here, $\dot{Z}_{ik}(t)/Z_{ik}(t-1)$, have already been modeled in the previous chapter, and are listed here again under different notations. They are:

1. Rate of change in proportion of perfectly irrigated paddy, $SCR_{i1}(t)$
2. Rate of change in proportion of quasi-perfectly irrigated paddy, $SCR_{i2}(t)$
3. Rate of change in proportion of temporary irrigated paddy, $SCR_{i3}(t)$
4. Rate of change in proportion of consolidated paddy, $SCR_{i4}(t)$
5. Rate of change in proportion of drained paddy, $SCR_{i5}(t)$
6. Rate of change in proportion of consolidated upland $SCR_{i6}(t)$
7. Rate of change in proportion of irrigated upland, $SCR_{i7}(t)$
8. Rate of change in proportion of new paddy land, $SLDR_{i1}(t)$
9. Rate of change in proportion of new upland, $SLDR_{i2}(t)$
10. Rate of change in what is called total factor productivity, due to research and extension, $YZD_{ij}(t)$.

Note that, because of the method of computation for SCR_{i6}, SCR_{i7}, $SLDR_{i1}$, $SLDR_{i2}$, the corresponding terms in Equation 6.3 must be read as $[b_{ijk}/Z_{ik}(t-1)] * [Z_{ik}(t) - Z_{ik}(t-1)]$ and the corresponding coefficients appeared in the computer program must be interpreted as $[b_{ijk}/Z_{ik}(t-1)]$ rather than b_{ijk} for these variables.

Product Supply Projection Model for Perennial Crop

Among 13 crops or crop groups covered in this study, at least two are perennial crops: fruit and mulberry, which are numbered $j = 5$ and $j = 11$, respectively. The perennial has a distinctive property in the production process. This necessitates different treatment of perennial and annual crops. Grass, some varieties of forage, and some industrial crops are also semiperennial and in this sense are similar to perennials, while in other respects, they are similar to annual crops. For simplicity, we treat these as annual crops. First, we review some useful theories in methodology or model applied to perennial crops. Based on the theories reviewed, we propose a model for perennial crop product supply projection.

The study of production or supply of perennial crops can be classified into two categories: (1) the conventional supply response study, and (2) projection of production or supply for agricultural development planning purposes. These categories cannot be independent, however, since the projection must be based on what farmers would respond to possible change in economic opportunity in future development.

Fernando [F.3] has made a projection of potential supply of tree crops for Ceylon. He indicated that "the state of supply analysis is relatively unsatisfactory compared to demand analysis" and adds that, "There are few really operationally useful elasticities of supply." He essentially assumes that "the area under tree crops has become stabilized." In this model, there is no room for economic and other social factors to affect the number of area planted, uprooted or cultivated.

He also indicates that "the projection of the average yield per acre presents many more problems than the projection of area." He adds that "average yields are affected by several factors simultaneously and the effect of each on output can be isolated and measured only with extreme difficulty." His principal projection methodology is to first separate areas with traditional tree varieties from those with high-yeild varieties, and small holdings from plantations and then to multiply each of these areas by fixed yield levels, respectively to get total production or supply. Once again, there are no economic or other social variables involved in determination of the yield level.

Fernando's study is by no means the only one that uses an accounting approach for projecting perennials or annual crop. We have seen already many examples. The essential point of this nonstructural or accounting model is, as already implied, an assumption that the farmer implicitly does not respond to a better economic opportunity, especially in terms of yield. However, there are many indications that the perennial crop farmer does take advantage of the better economic opportunity in the real world, although there are serious debates over the measurement of the producer responsiveness.

Bateman [B.3] reviews and summarizes the supply response studies on tree crops in developing countries in context of the market period (harvest), the short run as well as the long run. After discussing some shortcomings of the models he reviewed, he advances four alternative models. One common characteristic he introduces is a sort of unique farmers' expectation on prices of own product or alternative crops. In other words, farmers' expectations are formulated by Nerlovian expected price. That is, the supply is expressed as a function of the distributed lag prices. In this respect, his approach is ahead for examples of those by Stern [S.16], Wah [W.1], and many others, for example, who define supply as a function of a discrete lagged price, with or without other set of variables as independent variables. However, even Bateman assumes, as usual, that the yield level is fixed or given, with the excuse that "The expected yield pattern of most tree crops is relatively stable, and changes in potential yield occurs slowly."

Wah [W.1] sees one important realism correctly. That is, the change in composition of matured tree crop cohort affects the average yield. According to Wharton [W.2], the Marshallian-Cournot distinction between the short run and the long run is desired, especially for perennial crops. He points out that, even in the short run, output is still a function of variable inputs that Bateman, for example, recognizes but rules out. More important in perennial crop production, as he sees it, is that there exists a residual effect of variable inputs used. The same thing may be true for annual crops; however, the carryover effect is more significant for perennial crops and should not be neglected.

The theoretical consequence of this realism of the carryover effect, according to Wharton, is that "this fact suggests that stimulants (variable input uses) are useful for upward response to price but would perversely affect any subsequent downward price movement."

We have discussed some important facts that any useful model should take into consideration. First, a change in the composition of tree crop age cohorts is important in explaining changes in average yield. Second, the carryover or residual effect is also important in explaining supply response. The same is true for large animals such as dairy and beef cattle. Third, farmers' decisions on resource use for tree crops are not based on current price levels nor discrete single lag price such as $p(t-\tau)$ where $\tau = 1, . . . , \tau$, but on a distributed lag price. The same thing is more or less true for other crops or livestock. It is needless to say that variable input uses and structural changes defined in Chapters IV and V as important to perennial crops as to annual crops.

A production function for perennial crops that directly or indirectly reflects the theories reviewed above follows (subscripts are omitted to shorten notation):

$$6.4 \quad Y = A^* \prod_{\ell=1}^{\ell} \prod_{\tau=o}^{\tau} X_\ell^{W_\ell(t)*a_\ell(t-\tau)} (t-\tau)^* \prod_{k=1}^{k} Z_k^{b_k} (t) * V^c(t)$$

X_ℓ = so-called conventional production factor

Z_k = so-called nonconventional production factor and what we call structural change variable

V = age cohort composition[1]

A, a, b, c = appropriate production coefficients

W_ℓ = a weight given to coefficients of current and past input level, and $\sum_{\tau=o}^{\tau} W(t-\tau) = 1.0$

τ = maximum time range affecting on the current output or carryover period.

Equation 6.4 can be written:

$$6.5 \quad Y = A^* \prod_{\ell=1}^{\ell} X_\ell^{W_{\ell o}*a_\ell(t)} (t) * \prod_{k=1}^{k} Z_k^{b_k} (t) * V^c (t) * \prod_{\ell=1}^{\ell} \bar{X}_\ell^{\bar{W}_{\ell 1}*a_\ell(t)} (t)$$

Where: $\bar{X}_\ell^{\bar{W}_{\ell 1}*a_\ell(t)} (t) = \prod_{\tau=1}^{\tau} X_\ell^{W_{\ell(\tau)}*a(t-\tau)} (t-\tau)$

and $\bar{X}_\ell(t)$ is here interpreted as a distributed lag input and $W_{\ell o}$ + $W_{\ell 1}$ = 1.0. Once again, an economic interpretation of this formulation

---

[1]This age cohort composition can be easily computed from the perennial production subcomponent of the KASS model and the farm resource allocation component.

is that the past input rate influences the current output level with a weight of $W(\tau)$. The past input level can be, without generality, represented by a distributed lag value of the input. That is:

$$6.6 \quad \tau * \frac{d\bar{X}_{\ell(t)}}{dt} + \bar{X}_{\ell(t)} = X_{\ell(t)}$$

How much past input level will influence current output depends on the magnitude of W_o or W_1.

Parameter Estimation

In this chapter, we used a shorthand notation for each variable quite different from that used in the computer program. For convenience while discussiong parameter estimation problems, we try to introduce the variable names used in the computer program. For convenience, parameter estimation problems are discussed for both the variables shown in this chapter and the next as to how to estimate production parameters a_{ijl}, b_{ijk}, c_{ij}, etc., in Equations 6.1 - 6.5. Before discussing this problem, we will briefly discuss the validity of the Cobb-Douglas function. A problem stems from the unitary elasticity of substitution of the Cobb-Douglas function among production factors.

In reality, the elasticity of substitution may or may not be unitary, or may vary. Substitution between labor and capital inputs is usually discussed. The estimation method of the constant elasticity of substitution for two factor case is given by Arrow, et al. [A.9], and Brown [B.16], and for a many-factor case given also by Brown [B.16]. Variable elasticity substitution is discussed by Lu and Fletcher [L.20].

Even if labor is not one of the production factors included in Equations 6.1 and 6.4, it is suggested that the elasticity of substitution between labor and capital for Korean agricultural production be estimated in order to infer the validity of using the Cobb-Douglas function. Hayami and Ruttan [H.9] followed this procedure to justify using the Cobb-Douglas function. On the other hand, Lu [L.21] first checks whether the elasticity is constant or variable. In the case of constant elasticity, he tests whether the elasticity is unitary to make sure the Cobb-Douglas function is appropriate. While testing the validity of the assumption of variable or constant elasticity of substitution, he assumes there are only two inputs, labor and capital. By contrast, he includes many production factors when fitting Cobb-Douglas production functions.

Lu's approach seems more or less logical. To follow Lu's procedure, we need to add just one more independent variable, capital input over labor input, to the conventional estimation equation of the constant elasticity of substitution:

$$\text{Log } (V/L) = a + b \log W + c \log K/L$$

Where V stands for value added, L for labor input, K for capital input and a, b and c for appropriate parameters to be estimated. According to Lu, when $c = 0$, the function above reduces to the CES function. When $c = 0$ and $b = 1$, it reduces to the Cobb-Douglas function. When $c = 0$ and $b = 0$, it reduces to the fixed coefficient production function. It can be shown that when $b = 0$ and $c \neq 0$, the above equation also reduces to the Cobb-Douglas form.

However, here we adopt a simple procedure used by Hayami and Ruttan. The derived equation follows:

$$6.7 \quad \log (V/L) = 0.133 + 1.084 \log W, \; R^2 = 0.984$$

Where V stands for the average value added per farm from farming, L for weighted average labor input per farm by age and sex, and W for weighted average of farm wage rates by age and sex. All data come from yearbooks of Agricultural and Forestry Statistics. The regression coefficient or elasticity of substitution is significnatly different from zero at a high level. The null hypothesis that the elasticity of substitution is not different from unitary is rejected at 5 percent, but accepted at 2 percent of probability.

As a result of this statistical test, we do not insist that projections based on Equation 6.1 will always turn out unitary elasticity of substitution among capital items themself or between labor and capital. The behavior of the elasticity of substitution will be affected not only by relative prices among inputs, but also by the nature of technological changes generated by public policies, projects and programs. The insistence of Evenson [E.3] that the elasticity of substitution between biological and mechanical inputs is relatively low, and of Srivartava and Heady [S.14] that the elasticity is changing should be interpreted as consequences of particular public policies.

Let us now discuss the problem of estimating production coefficients, first for $a_{ij\ell}$ in the production function in Equation 6.1. Any of several types of data could be used: time series data, cross-sectional data and experimental data; however, none of these sources was readily available and they are expensive to collect. Even if one of them is available, it is not very easy to obtain appropriate signs of the regression coefficients for variables considered. There are a number of examples showing that one or more of them do not have the signs predicted by the theory. For example, Alcantara and Prata's [A.7] production elasticity derived from total cost function has a negative sign for machinery input. Should the farmer be interpreted as behaving irrationally, since less or no machinery use will bring more production, according to his result? What is wrong? It should be interpreted that his survey design, resource classification or specification was inappropriate. This means that it is difficult to secure even the correct sign, not to mention correct magnitudes.

Because of this difficulty, we use an indirect method of estimating the production coefficients based on the assumption that farmers behave rationally under the perfect competition. Assume the following production function for simplicity:

6.8 $Y = aX^b$

The first-order condition for profit maximization is:

6.9 $dy/dx = Px/Py$ or

6.10 $dy/dx = baX^{b-1} = bY/X = Px/Py$

when we rearrange it, we have:

6.11 $b = [Px*X]/[Py*Y]$

Where Px stands for input price, Py for production price, X for input level, and Y for output level. Of course, the left side of Equation 6.11 is the appropriate production coefficient or elasticity, and the right side is called the factor share. In other words, this factor share, which can easily be collected even in the least developed countries [the terminology adopted from (0.1)], is used as a proxy of the production coefficient in this study. This approach to estimating this coefficient is not new in economic literature. Many studies on aggregate production function use this approach, including that of Solo [S.11].

Ray and Heady [R.2 and R.3] use the same approach in formulating a simulation model for U.S. agriculture. Tweeten and Quance [T.5] use this concept to estimate aggregate supply elasticity, and Quance [Q.1] uses it for estimating the marginal value product to examine capital gains and losses, based asset fixity theory.

Next, we must ask whether the factor share or productivity coefficient is stable over time. Tyner and Tweeten [T.6] find that the productivity coefficient changes over time and diverges from the equilibrium position, and suggest an adjustment model to correct the factor share estimates. This model is based on the Nerlovian distributed lag adjustment model.

We approach this problem slightly differently. That is, the productivity coefficient, ALP, is estimated as follows:

$$6.12\quad ALP_{ij\ell}(t) = PXD_{i\ell}(t) * FXD_{ij\ell}(t)/[PD_{ij}(t) * YD_{ij}(t)]$$

Where PXD, FXD, PD and YD, respectively, are distributed lag variables of factor price, PX, factor used, FX, product price, PAVG, and yield, YLD.

In an ideal situation, it would be very nice if all parameters were estimated simultaneously from one data source. However, this would be very difficult, if not impossible, in practice. Thus, what we have done is to construct the production function after separate estimation of each of the individual partial production elasticities; that is a pragmatic synthetic approach similar to that used by Ray and Heady [R.2, R.3] in their simulation model.

The first attempt is to obtain production elasticities of rice irrigation. Ruttan [R.10] hypothesizes that rice yield differences among regions or locations are due to differences in irrigation levels. since other technology would be similar among regions.[2] Based on this hypothesis, the following production function is fitted, using time series provincial data from 1962 to 1972:

6.13 $Y = f\ (Z_i, D_i)$

Where Y stands for average yield in each province in each year, Z_i for areas under various irrigation types, and D_i for some dummy variables including trend. The actual model adopted in this study, among many alternative specifications is a linear function in log, both for dependent and independent variables. The result is shown in Table 6.1.

A similar analysis was done by Lee [L.12] for Taiwan agriculture. Can it be said that the coefficients of Z_i in the first low in Table 6.1

---

[2]This hypothesis appears in several articles, with or without co-author, for example [H.27].

represent only the effect of irrigation? An improvement in or addition of irrigation certainly induces us to use more conventional inputs. The above coefficients represent the joint effect of all these factor uses. This joint effect is illustrated in Figure 6.3.

Table 6.1. Productivity Coefficients of Rice Irrigation.

	Constant	Independent Variables[a]			Total Paddy	Trend	R^2
		Z_1	Z_2	Z_3			
Coefficients	1.571	0.200	0.159	0.107	-0.361	0.464	0.435
t-Value	2.33	3.27	2.28	1.01	1.82	1.22	
Probability	0.02	0.01	0.02	0.30	0.05	0.20	

[a] Z_1 = perfectly irrigated paddy/total paddy

Z_2 = quasi-perfectly irrigated paddy/total paddy

Z_3 = temporary irrigated paddy/total paddy

Source: Year Books of Agriculture and Forestry Statistics, MAF. 1962-72.

Due to a change in the other production factor use, the production function has shifted among subfunctions upward and rightward. An empirical illustration of this nature is found in Herdt and Mellor [H.23], where they derive rice-fertilizer production functions in the U.S. and India and contrast them to show the nature of production function shift due to differences in factor use. Suppose P'P' is parallel to pp, which is a price ratio line in Figure 6.3. Then the optimum input and output level with addition of a new factor are, respectively, f and a, whereas those without a new factor are e and c, respectively. As clearly seen, the effect of the new factor on the production level

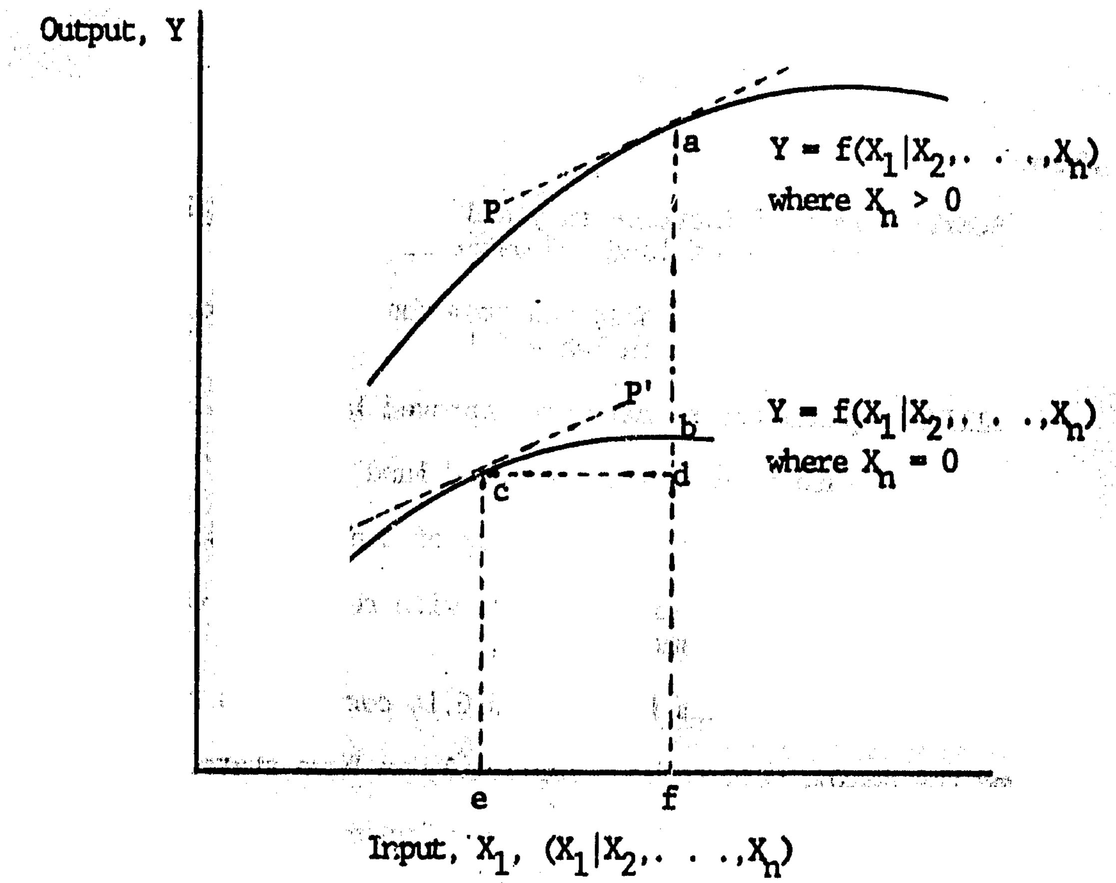

Figure 6.3. Production function shift among subfunctions due to addition of a new production factor.

is certainly not ad, but ab, and bd is an effect of an increase in the so-called conventional input use from e to f.

What we observe from the real world is not ab, but ad. Therefore, to measure the correct net effect of adding a new factor we must first measure the difference in conventional resource use with and without a new factor, ef, and compute an increase in production due to the increase in factor uses, bd. Then the net effect is obtained by subtracting bd plus ce from af. In mathematical terms, this can be accomplished:

$$6.14 \quad SCEYYY_{ij}(t) = \sum_k YLDPA_{ijk} * ALLPA_{ijk} * SCR_{ik} - \sum_{\ell k}\sum ALP_{ij\ell}(t) * ASC_{ijk\ell} * ALLPA_{ijk} * SCR_{ik}(t)$$

Where:

SCEYYY = rate of increase in yield due to technological change in terms of land and water development.

YLDPA = coefficients observed from the real world, such as coefficients in Table 6.1

ALLPA = parameter to allocate improved land

SCR = rate of change in improved land

ALP = productivity coefficients of conventional inputs

ASC = elasticity of factor use with respect to change in improved land

Thus, the first term in Equation 6.14 corresponds to ad in Figure 6.1 and the second term to bd. Implicitly we have stated a method of computing the net effect of adding a new factor in terms of improved land. However, the same principle is used for computing others, such as variety change, age cohort change, etc.

How about productivity coefficients of the other structural change terms in the production function in Equation 6.1. Basically, they can be obtained by statistical analysis of farm management data, or we can observe the difference in productivity between improved and unimproved land from cross-sectional data. One interesting method of obtaining productivity coefficients of irrigation for upland is given by Parvin [P.2]. He contrasts the yield in dry years to that in wet years, using data from experiment stations where the technology used is likely stable. At any rate, the estimation technique seems available for varying situations. However, the necessary data are not available or readily collected. Thus we temporarily use what might be called "gestimate" data based on this author's experience and results from various case studies for structural change terms other than paddy irrigation, total productivity and past input use for perennials. The same type of data is used for ASC, which is elasticity of factor use with respect to structural change.

In summary, one of the basic structural relationships in this chapter is the production function in Equation 6.1 and therefore the derived projection Equation 6.3, including those for perennial crops. The projection equation (Equation 6.3) can be derived from any form of production function, including exponential functions such as Equation 6.1. There are two reasons for having the Cobb-Douglas production function explicitly in this study: First, with this form of production function, mathematical manipulation is much easier, for example, in deriving factor demand function. Second, this form of production function can reveal certain interaction effects among independent variables in the production function; however, it was found later when computer outputs were analysed that Equation 6.3 was unable to handle interaction effects among structural change variables.

The level of structural change variable is determined independently from that of the so-called conventional input. In other words, interaction effects among and between so-called conventional inputs and structural change variables are considered separately in Chapter VII.

The interaction effect among structural change variables are important. To allow this interaction in projection, there seem to be at least three options: (1) to use the other explicit form of the production functions, (2) to use the production function in Equation 6.1 directly for projection purpose, and (3) to insert some mechanism to reflect interaction in Equation 6.3.

This problem needs to be discussed relative to availability of required data for estimating productivity coefficients, as well as for parameters in factor demand function that will be disucssed in the next chapter. While collecting data for the purpose of refining the model presented in this study, more appropriate forms of production functions or yield projection equations should be sought

CHAPTER VII

FACTOR DEMAND PROJECTION

Production levels and, hence, supply responses for agricultural products are the consequences of resource use. Thus, demand for production factor plays a very important role in explaining changes in production and, in turn, growth rates. In the previous chapter, we did not explain how demand for production factor is determined; this is the main subject of this chapter.

It is logical for us to first discuss specifically what kinds of production factors we are considering. Production factor can be classified in many ways, depending on the objective of study. Heady [H.11, p. 299-300] gives some expamples and basis for classification. Johnson [J.4, and J.16] classifies productive resources in order to study the nature of resource fixity and production response. Our primary purposes in this study are: (1) to explain production response, and (2) to supply the farm resource allocation component model with variable costs for each crop in each region and input-output coefficient requirements. Inasmuch as each production factor classified appears in the production function together with the other classified factors, classification must be based on a useful theory. A basic theory is given by Johnson [J.2]. According to him, resources or production factors that perfectly complement or supplement each other should not appear in a production function together as independent variables. Otherwise, multicollinearity problems arise.

For our purposes, and based on a theory suggested by Johnson, the production factor is classified as follows:

1. Fertilizer
2. Pesticides and insecticides
3. Other materials
4. Labor in spring labor peak season
5. Labor in fall labor peak season

Note that: (1) land is not included, because we are dealing with production per unit of land--yield. (2) What are often called fixed resources, such as buildings, are not explicitly included. Since we are dealing with the service of flow, not stock itself, maintenance, depreciation, and other costs associated with these fixed resources are included in other materials.[1] (3) The other type of fixed resource, farm machinery, is also ruled out, as explained in Chapter III. (4) Still other types of fixed resources, fruit and mulberry trees, are also ruled out since the farm resource allocation and perennial crop production subcomponents deal with that matter. As explained in Chapter III, the last two items, two types of labor, do not appear directly in the production function, but demand projections for labor are made.

How do we go about making projections of these factor demands? Despite "While the problems of agriculture are directly those of commodity supply and price, basically they are problems of resource demand and supply" [II.19, p. 2], it seems that "one of the neglected

---

[1]This cost item includes costs associated with seeds, buildings, farm implements, materials, etc.

areas in agricultural demand analysis has been the demand by farmers for inputs produced by nonfarmers" [C.10].

Some examples of factor demand studies are found in Griliches [G.9 and G.10], Cromarty [C.10], Heady and Yeh [H.20], Heady and Tweeten [H.10, p. 154-374], Hayami [H.8], Sung, et al. [S.18], etc. Worthwhile to mention in connection with these studies are: (1) Griliches [G.10] and Sung, et al. [S.8] use a Nerlovian distributed lag model. (2) Cromarty [C.10] introduces farm income and interest rate in demand function as independent variables, where Heady and Yeh [H.20] include income trend in addition to these variables, as a proxy of capital budget. (3) the demand structure connecting direction, magnitude, and duration of price change does not seem well studied, despite Boyne and Johnson [B.13] clearly finding some evidence. (4) The model by Sung, et al. is constructed primarily for making demand projection for fertilizer. Inasmuch as they try to include some technological changes as function shifters, higher credibility should be given to this effort. However, they miss a very important variable in explaining a change in total demand for fertilizer. Due to genetic characteristics of crops, some require more fertilizer than others. For example, vegetables, fruits, potatoes, etc., belong to the former type, and demand on these commodities and, hence, production are expected to grow more rapidly. Without considering this adjustment, the projection for fertilizer demand would be strongly underbiased. There are also some other evidences for underestimation. They do not consider possible demand shifts such as upland irrigation, drainage, consolidation, etc.

On the other hand, there is another type of factor demand study, which is derived from production function, based on profit maximization and other static assumptions. The example of deriving factor demand from a production function is given in Heady and Tweeten [H.19], Heady and Dillon [H.18], Lee [L.4], etc. A good example of a factor demand study of this nature based on cross-sectional data is given in Ruttan [R.9], which we will soon examine comparatively and more intensively. Similar demand functions can also be derived from a linear programming model through parametric programming techniques [Lee (L.5)] and of budget procedures.

Ruttan's study cited above projects demand for irrigated land. He begins by saying:

> "Economists have long been concerned by the fact that projection of resource use have been made on the basis of the quantity of inputs "required" to support some projected level of final output. . .The "requirement is ordinarily determined by applying a factor or coefficient to a projected level of output. . .The difficulty with such a projection is that they cannot encompass the tremendous capacity of the economy to adjust to changes in the availability and cost of resources. Requirement projections implicitly assume that the projected amount of the input will be used regardless of the costs of supplying it"[R.4, p. 1].

After criticizing the requirement approach, he advances a method for determining the economic demand for irrigation. First, he derives a regional agricultural production function to get the productivity of irrigated land. The production function is specified in terms of not only the irrigated land, but also other relevant production factors customarily used. Once the productivity coefficients and costs involved in irrigation are known, he is ready to determine the optimum use of irrigated land. Then he projects demand for irrigated land to 1980.

He makes two sets of projections, one based on what he calls the demand model and the other based on what he calls the equilibrium model. Both models stem from what he calls the productivity model, and the only difference seems to be in assumptions. In the demand model, he assumes a regional production growth rate, whereas in the equilibrium model, without assumptions as to production growth rates, the optimum input of irrigated land is projected with the usual assumption of profit maximization.

Now we are ready to propose an alternative factor demand projection model. The regression analysis approach has several disadvantages, as noted in previous chapters, but provides many insights to be considered in a useful projection model. In short, again a pragmatic approach based on the structure of the agricultural production system itself and some basic relevant findings are incorporated into the proposed model. First, we make an assumption of profit maximization. If this assumption and those made in Chapter VI are accepted as a first approximation, projection of factor demand is a mechanical matter based on a simple optimization technique. Whether or not the Korean farmer responds to the economic opportunity and to what degree is an important question. This question along would be a good topic for a Ph.D. dissertation. Thus, we leave this question without intensive examination, but call attention to relevant studies such as these by Huh and Lee [H.28], Lee [L.4], Seol [S.6], Kim [K.4], and Ferris and Suh [F.4].

The next question to be examined is whether or not the profit maximization assumption is appropriate. There are endless examples of economic models that adapt this assumption for application in either the LDCs or others, although this assumption has occasionally been challenged. Is this assumption totally inappropriate? If so, in what respect?

It seems that the bad thing is not the assumption itself, but that the researcher often seems unable to consider other behavior of producers. That is, producers, regardless of whether the firm is large or small, and whether or not it operates in an LDC, maximize more than net money return.[2] If a researcher fails to recognize this fact, he must be criticized. Is the farmer in the Midwest in the U.S. a straight forward profit maximizer? Instead of answering this question, let us ask if the giant American corporation such as GM or Ford a straightforward profit maximizer? How do you interpret the fact if they do (or used to) hesitate to hire a Negro worker, other things being equal? If so, should they be called nonprofit-motivated firms?

What we want to emphasize is that there are many sets of normative behavior constraints in making production decisions. Researchers ought to not only criticize profit maximization assumptions, but also identify other values that may well have a trade-off relationship with monetary values. Rossmiller, et al. [R.7], for example, identify value constellations for Korean agriculture at the macro level, as seen in Chapter III. Otherwise, we have to reconstruct a body of a new economic theory, after destroying established standard economic

---

[2] For a more detailed study of managerial processes of farmer decision, see Johnson, et al. [J.13].

theory. Fortunately, the existing economic theory is not so bad that it should be destroyed. Then what are the most appropriate constraints a useful micro model has to consider in order to be more realistic?

As a matter of fact, all of the relevant constraints may not be studied, mainly due to a lack of appropriate measurement of variables, such as psychological factors, due to difficulty of conceptualization, etc. Constraints or modividations presented in this study have specifically involved resource constraints and behavioral constraints. Apart from constraints of both types defined in the farm resource allocation component model, fixity of capital budget, and uncertainty and resource fixity, which are the modified neoclassical economic theory due to Johnson [J.16, Ch. 3], will be specifically considered in this model.

Factor Demand Projection Model

With this intorduction, let us construct a demand projection model. The production function presented in Chapter VI is represented here without regional subscript and time index for the convenience in Equation 7.1:

$$7.1 \quad Y_j = A_j \, \Pi X_{j\ell}^{a_{j\ell}} \, \Pi Z_k^{b_{jk}}$$

with this production function, the resultant profit function is:

$$\begin{aligned} 7.2 \quad \Pi = {} & \Sigma P_{yj} Y_j - \Sigma\Sigma P_{x\ell} X_{j\ell} - F - \Sigma R_i K_i - \lambda[\Sigma\Sigma P_{x\ell} X_{j\ell} + F - K_1 \\ & - K_2 - K_3 - K_4 + K_5] \qquad - U_1(K_1 - \bar{K}_1) \\ & \qquad - U_2(K_2 - \bar{K}_2) \\ & \qquad - U_3(K_3 - \bar{K}_3) \\ & \qquad - U_4(K_4 - \bar{K}_4) \\ & \qquad - U_5(K_5 - \bar{K}_1) \end{aligned}$$

Where:

P_y = product price

P_x = input price

F = fixed costs (if any)

K_1 = farmer's own capital used for farming

K_2 = credit from government-supported institutions

K_3 = credit from private loans with low interest rates

K_4 = credit from private loans with high interest rates

$\bar{K}_i$ = respective total available amount of capital budget

λ, U_i = respective lagrangian multiplier

K_5 = farmer's own capital disposed for nonfarm uses

R_i = appropriate interest rates paid or received

The meaning of Equation 7.2 will be self-evident to the reader familiar with the elementary mathematical economics. That is, the profit realized is defined as the difference between total revenue, $\Sigma P_{yj} Y_j$, and total costs, $\Sigma\Sigma P_{X\ell} X_{j\ell} + F + \Sigma R_i K_i$, but (1) total expenditures, $\Sigma\Sigma P_{X\ell} X_{j\ell} + F$, should not exceed the capital budget made available, $K_1 + K_2$ $K_3 + K_4 - K_5$, (2) farmer's own capital used for farming should not exceed that available, (3) credit from government source or others should not exceed what is made available, etc. and, (4) farmer's own capital salvaged should not exceed what he has.

The first-order conditions for profit maximization are:

$$7.3 \quad \frac{\partial \Pi}{\partial X_{j\ell}} = P_{yj} \frac{\alpha Y_j}{\alpha X_{j\ell}} - Px_\ell - \lambda \, Px_\ell = 0$$

$$7.4 \quad \frac{\partial \Pi}{\partial k_1} = -R_\omega + \lambda - \mu_1 \gtreqless 0$$

7.5 $\frac{\partial \Pi}{\partial k_2} = -R_2 + \lambda - \mu_2 \geq 0$

7.6 $\frac{\partial \Pi}{\partial k_3} = -R_3 + \lambda - \mu_3 \geq 0$

7.7 $\frac{\partial \Pi}{\partial k_4} = -R_4 + \lambda - \mu_4 \geq 0$

7.8 $\frac{\partial \Pi}{\partial k_5} = -R_5 - \lambda - \mu_5 \geq 0$

7.9 $\frac{\partial \Pi}{\partial \tau} = \Sigma\Sigma Px_{\ell} X_{j\ell} + F - k_1 - k_2 - k_3 - k_4 + k_5 = 0$

7.10 $\frac{\partial \Pi}{\partial u_1} = k_1 - \overline{k_1} \geq 0$

7.11 $\frac{\partial \Pi}{\partial u_2} = k_2 - \overline{k_2} \geq 0$

7.12 $\frac{\partial \Pi}{\partial u_3} = k_3 - \overline{k_3} \geq 0$

7.13 $\frac{\partial \Pi}{\partial u_4} = k_4 - \overline{k_4} \geq 0$

7.14 $\frac{\partial \Pi}{\partial u_5} = k_5 - \overline{k_1} \geq 0$

The factor demand function of $X_{j\ell}$ is defined as the solution of Equations 7.3 - 7.14 simultaneously. That is, the optimum input rates and borrowing or disposal rates are determined by the system of equations above. But how do we solve this system of equations simultaneously either to get the optimum rates or to derive factor demand function?

Heady and Dillon [H.16] and Heady and Tweeten [H.19] discuss the solution methods for the optimum input rate generally or the unconstrained Cobb-Douglas production function. Lee [L.4] discusses a method of deriving it from the constrained production function in quadratic form. Lau and Yotopoulos [L.1] and Zarembka [Z.1, Ch. 8] provide a method of driving the factor demand function from the unconstrained Cobb-Douglas production function. At any rate, there is without a doubt no analytical solution for the above system of equation. Then how do we go about deriving factor demand function subject to constraints imposed? We are going to give an indirect solution method here, without losing any generality. Let us first write Equation 7.3 in explicit form by substituting Y_j in Equation 7.1, assuming that there are three production factors. Then we have:

$$7.15 \quad \frac{\partial\Pi}{\partial X_{j1}} = Py_j\left[A_j a_{j1} X_{j1}^{a_{j1}-1}\; X_{j2}^{a_{j2}}\; X_{j3}^{a_{j3}}\; \Pi Z_k^{b_{jk}}\right] - Px_1 - \lambda_1 Px_1 = 0$$

$$7.16 \quad \frac{\partial\Pi}{\partial X_{j2}} = Py_j\left[A_j a_{j2}\; X_{j1}^{a_{j1}}\; X_{j2}^{a_{j2}-1}\; X_{j3}^{a_{j3}}\; \Pi Z_k^{b_{jk}}\right] - Px_2 - \lambda_2 Px_2 = 0$$

$$7.17 \quad \frac{\partial\Pi}{\partial X_{j3}} = Py_j\left[A_j a_{j3}\; X_{j1}^{a_{j1}}\; X_{j2}^{a_{j2}}\; X_{j3}^{a_{j3}-1}\; \Pi Z_k^{b_{jk}}\right] - Px_3 - \lambda_3 Px_3 = 0$$

where the Lagrangian multiplier is differentiated among inputs, just for exposition, but this differentiation will soon be withdrawn. At an equilibrium, all the variable inputs should be used so that the least cost combination is secured. The least cost combination between X_{j1} and X_{j2} is secured when the following condition holds:

$$7.18 \quad \frac{\partial Y_j}{\partial X_{j1}} \Big/ \frac{\partial Y_j}{\partial X_{j2}} = \frac{\partial X_{j2}}{\partial X_{j1}} = \frac{a_{j1}X_{j2}}{a_{j2}X_{j1}} = \frac{(1+\lambda_1)\; Px_1/Py_j}{(1+\lambda_2)\; Px_2/Py_j}$$

which can be simplified as follows:

$$7.19 \quad X_{j2} = \frac{(1+\lambda_1)Px_1}{Py_j}\left(\frac{(1+\lambda_2)Px_2}{Py_j}\right)^{-1} a_{j1}^{-1} a_{j2} X_{j1}$$

which is called the iso-quants equation [see Heady and Dillon (H.18)]. The iso-quants equation between X_{j1} and X_{j3} can be similarly derived as follows:

$$7.20 \quad X_{j3} = \frac{(1+\lambda_1)Px_1}{Py_j} \left(\frac{(1+\lambda_3)Px_3}{Py_j}\right)^{-1} a_{j1}^{-1} a_{j3} X_{j1}$$

Now let us substitute Equations 7.10 and 7.20 for X_{j2} and X_{j3} in the production function of Equation 7.1 to obtain:

$$7.21 \quad Y_j = A_j X_{j1}^{a_{j1}} [V_1 V_2^{-1} a_{j1}^{-1} a_{j2} X_{j1}]^{a_{j2}} [V_1 V_3^{-1} a_{j1}^{-1} a_{j3} X_{j1}]^{a_{j3}} \Pi Z_k^{b_{jk}}$$

where:

$$7.22 \quad V_i = \frac{(1+\lambda_i)Px_i}{Py_j}$$

Noting that the production function in Equation 7.21 is now a function of X_{j1} alone, it can be rewritten as follows:

$$7.23 \quad Y_j = A_j V_1^{a_{j2}+a_{j3}} V_2^{-a_{j2}} V_3^{-a_{j3}} a_{j1}^{-a_{j2}-a_{j3}} a_{j2}^{a_{j2}} a_{j3}^{a_{j3}} X_{j1}^{a_{j1}+a_{j2}+a_{j3}} \Pi Z_k^{b_{jk}}$$

The optimum input rate of X_{j1} is determined when the marginal value product is equal to the marginal factor cost, or the marginal physical product is equal to the price ratio; that is:

$$7.24 \quad \frac{\partial Y_j}{\partial X_{j1}} = [a_{j1} + a_{j2} + a_{j3}]\, A_j V_1^{a_{j2}+a_{j3}} V_2^{-a_{j2}} V_3^{-a_{j3}}$$

$$a_{j1}^{-a_{j2}-a_{j3}}\, a_{j2}^{a_{j2}}\, a_{j3}^{a_{j3}}\, X_{j1}^{a_{j1}+a_{j2}+a_{j3}-1}$$

$$\Pi Z_k^{b_{jk}} = \frac{(1+\lambda_1)Px_1}{Py_j}$$

Solve Equation 7.24 in terms of X_{j1} in order to derive the factor demand function:

$$7.25 \quad X_{j1} = \left[S_j A_j V_1^{a_{j2}+a_{j3}-1} V_2^{-a_{j2}} V_3^{-a_{j3}} a_{j1}^{-a_{j2}-a_{j3}} a_{j2}^{a_{j3}} a_{j3}^{a_j} \right.$$

$$\left. \Pi Z_k^{b_{jk}} \right]^{\frac{1}{1-S_j}}$$

Where $S_j = a_{j1} + a_{j2} + a_{j3}$.

Now let us assume that the net marginal returns to capital expenditure on each factor, λ_ℓ, are equal to each other. In fact this is essentially one of the efficiency criteria for resource use. Equation 7.25 can then be written:

$$7.26 \quad X_{j1} = \left[A_j S_j a_{j1}^{-s_j} Py_j Px_1^{s-1} (1+\lambda)^{-1} \left[\Pi_\ell a_{j\ell}^{a_{j\ell}} Px_\ell^{-a_{j\ell}} \right] \right.$$

$$\left. \Pi Z_k^{b_{jk}} \right]^{\frac{1}{1-S_j}}$$

which is the final derivation of factor demand function of X_{j1}. The factor demand function can be written more generally as follows:

$$7.27 \quad X_{jn} = \left[A_j S_j \, a_{jn}^{-S_j} \, Py_j Px_n^{S_j - 1} \, (1+\lambda)^{-1} \left[\prod_o a_{j\ell}^{a_{j\ell}} \, Px_\ell^{-a_{j\ell}} \right] \prod Z_k^{b_{jk}} \right]^{\frac{1}{1-S_i}}$$

where n is a dummy to indicate which input among ℓ inputs we are taking under consideration.

Before proceeding to the next step, let us digress to examine some important economic relationships from our final factor demand function. Let us define the elasticities of demand for factor X_{j1} with respect to own price, cross prices and end product price, respectively, as follows:

$$7.28 \quad \varepsilon 1,1 = \frac{\partial X_{j1}}{\partial Px_1} \cdot \frac{Px_1}{Xj_1} = \frac{S_j - a_{j1} - 1}{1 - S_j}$$

$$7.29 \quad \varepsilon 1,2 = \frac{\partial X_{j1}}{\partial P_{x2}} \cdot \frac{P_{x3}}{X_{j1}} = \frac{-a_{j2}}{1 - S_j}$$

$$7.30 \quad \varepsilon 1,3 = \frac{\partial X_{j1}}{\partial P_{x3}} \cdot \frac{P_{x3}}{X_{j1}} = \frac{-a_{j3}}{1 - S_j}$$

$$7.31 \quad \varepsilon 1,y = \frac{\partial X_{j1}}{\partial P_{yj}} \cdot \frac{P_{yj}}{X_{j1}} = \frac{1}{1 - S_j}$$

Observe that the following relationship holds:

$$7.32 \quad \sum_{i=1}^{3} \varepsilon 1.i = -\varepsilon 1.y$$

The above relationship insists for example, that when all factor prices and product price increase by the same proportion, there is no change in optimum input level. Would this be true regardless of the capital budget level? Clearly not. Then what is wrong? The net marginal returns to capital expenditure, λ, is a function of all kinds of prices and budget constraints, in addition to technical coefficients. In order to derive the correct and true relationship and go ahead to the next step toward solving the system of equations in Equations 7.3 - 7.14, we insure that total expenditures will not exceed total available capital budget; that is, we make the relationship in Equation 7.9 hold. What we need to do is: (1) substitute the factor demand function for all inputs for each product in Equation 7.9, and (2) solve the resultant equation in terms of the net marginal returns to capital expenditure, λ, and (3) substitute the resultant equation for λ into the individual factor demand function. Then the final equation will be true factor demand function constrained by capital, and we will be ready to derive more realistic homogenity or other relevant consistency conditions.

Unfortunately, there is no analytical solution for this particular type of production function. This author [L.4] has shown that the fundamental relationships in commodity demand advanced by Frisch [F.12] hold equally in factor demand with a set of production functions in a form of quadratic function. The relevant relationships are Engel aggregation and homogenity condition. The former says that the sum of budget elasticities weighted with the budget proportion $P_{x\ell}X_{j\ell}/\Sigma\Sigma P_{x\ell}\cdot X_{j\ell}$ is unity, and the latter says the sum of demand elasticities with respect to own and cross factor prices is equal to budget elasticity in the absolute value for a commodity. That is, the homogenity condition in Equation 7.32 no longer exists in a case of a constrained profit function. Instead, when all factor prices and budget increase by the same proportion, there is no change in factor demand. This should be interpreted carefully. This relationship holds only for marginal changes in the neighborhood of the previous optimum input levels.

Let us now go back to the main subject. To insure that the relationships in Equations 7.3 - 7.14 hold, Equation 7.27 is expanded by the Taylor series, as in Chapter VI, to obtain:

$$7.33 \quad X_{ij\ell} = \left[1 + \frac{1}{1-S_{ij}} \frac{\dot{P}_{yij}(t)}{P_{yij}(t-1)} - \frac{\dot{P}_{xi\ell}(t)}{P_{xi\ell}(t-1)} + \sum_{\ell} \frac{a_{ij\ell}}{1-S_{ij}} \frac{\dot{P}_{xi\ell}(t)}{P_{xi\ell}(t-1)} + \frac{1}{1-S_{ij}} \frac{\dot{\gamma}_i(t)}{\gamma_i(t-1)} + \sum_{k} \frac{b_{ij\ell k}}{1-S_{ij}} \frac{\dot{Z}_{ik}(t)}{Z_{ik}(t-1)}\right] * X_{ij\ell}(t-1)$$

Where $\gamma = 1 + \lambda$, and i for region, j on crops and ℓ for factor. This is a final projection equation of factor demand for annual crops For the perennial crops, the appropriate terms should be added. But γ, is still an unknown variable.

Now in order to make Equation 7.9 hold and to determine γ, let us substitute all factor demand functions into Equation 7.9, and after including particular terms for perennials and rearrangement, we have

$$7.34 \quad \sum_j \sum_\ell P_{xi\ell}(t)\, X_{ij\ell}(t) = \sum\sum P_{xi\ell}(t)\, X_{ij\ell}(t-1)$$

$$+ \sum\sum \alpha 1_{ij\ell} \frac{\dot{P}_{yij}(t)}{P_{yij}(t-1)} \cdot Px_{i\ell}(t) \cdot X_{ij\ell}(t-1)$$

$$- \sum\sum \alpha 2_{ij\ell} \frac{\dot{P}_{xi\ell}(t)}{P_{xi\ell}(t-1)}\; P_{xi\ell}(t)\; X_{ij\ell}(t-1)$$

$$- \sum\sum \alpha 3_{ij\ell} \frac{\dot{P}_{xi\ell}(t)}{P_{xi\ell}(t-1)}\; P_{xi\ell}(t)\; X_{ij\ell}(t-1)$$

$$- \sum\sum \alpha 4_{ij\ell} \frac{\dot{\gamma i}(t)}{\gamma i(t-1)}\; P_{xi\ell}(t)\; X_{ij\ell}(t-1)$$

$$+ \sum_j \sum_\ell \sum_k \alpha 5_{ij\ell} \frac{\dot{Z}_{ik}(t)}{Z_{ik}(t)}\; P_{xi\ell}(t)\; X_{ij\ell}(t-1)$$

Which is total expenditure on variable inputs. Note that the notation for parameters has been changed for simplicity. In equilibrium, this must not be exceed the available capital budget (K_i); that is:

$$7.35 \quad \sum\sum P_{xi\ell}(t)\; X_{ij\ell}(t) \leq K_i(t)$$

Where $K_i(t) = K_1 + K_2 + K_3 + K_4 - F - K_5$ for each region.
After substituting $K_i(t)$ for $\sum\sum P_{xi\ell}(t)\; X_{ij\ell}(t)$ in Equation 7.34, solve the resultant equation in terms of $\gamma_i(t)$ to obtain:

$$7.36 \quad \gamma_i(t) = \frac{\gamma i(t-1)}{\sum\sum \alpha 4_{ij\ell}} \Bigg[1 + \sum\sum \alpha 1_{ij\ell} \frac{\dot{P}_{yij}(t)}{P_{yij}(t-1)} - \sum\sum \alpha 2_{ij\ell} \frac{\dot{P}_{xi\ell}(t)}{P_{xi\ell}(t-1)} - \sum\sum \alpha 3_{ij\ell} \frac{\dot{P}_{xi\ell}(t)}{P_{xi\ell}(t-1)} + \sum\sum\sum \alpha 5_{ij\ell} \frac{\dot{Z}_{ik}(t)}{Z_{ik}(t-1)} \Bigg]$$

$$7.36\ \text{(cont.)} \quad \frac{\gamma_i(t-1)K_i(t)}{\Sigma\Sigma\alpha 4_{ij\ell}P_{x\ell}(t)\ X_{ij\ell}(t-1)} - \gamma_i(t-1)$$

which is the final projection equation for the gross marginal returns to capital expenditure for variable inputs.

Let us make sure we understand the meaning of γ; that is:

$$7.36 \quad \gamma_i = (1 + \lambda_i) = \frac{P_{yij}\alpha Y_{ij}}{\alpha X_{ij\ell}} / P_{xi\ell}$$

where λ is a sort of net marginal rate of internal return to capital. With this understanding, let us play a game to insure that the relationships in Equations 7.4 - 7.8 and 7.10 - 7.14 hold, since we have already made Equation 7.3 and 7.9 hold. And let us postulate the following stepped capital supply function. First, substitute the farmer's own capital, K_1, into Equation 7.36, and solve it. The possible outcomes are:

1. $\gamma_i > R_1$
2. $\lambda_i = R_1$
3. $\lambda_i < R_1$

If possibility 2 is a case, it is not at all worthwhile to vary capital budget, and K_1 is by definition fixed. The corresponding internal return is R_1. If possibility 3 is the case, farmer's own capital is no longer fixed, and the farmer disposes of some of his capital, K_1, so that the internal return equals R_5. This is the case when the marginal value product curve turns out NMVP1,[3] in Figure 7.1. $K_1 - K_1$*

[3]NMVP stands for the net marginal return to capital that is, the locus of λ as a function of capital constraint with given values of all other parameters.

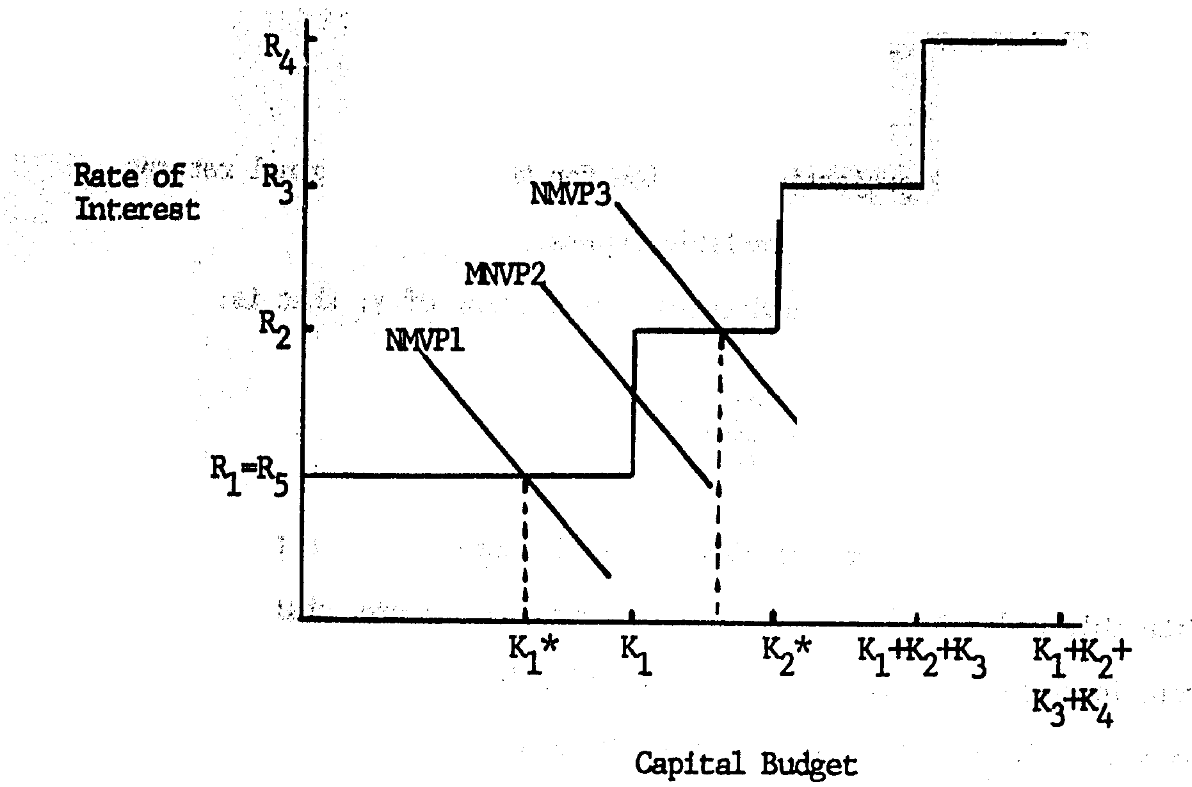

Figure 7.1. Stepped capital supply function (Hypothetical).

is salvaged. If possibility 1 is a case, since the capital constraint cannot be said to be fixed, use $K_1 + K_2$ for K in Equation 7.36 to recompute γ_i, hence, λ_i. Again, the possible outcomes are:

1. $\lambda_i > R_2$
2. $\lambda_i = R_2$
3. $\lambda_i < R_2$

When possibility 2 is the case, the farmer's own capital, K_1, plus government-supplied capital, K_2, is fixed and used for farming and the appropriate internal return, λ, is equal to R^2. When possibility 3 is the case, it is not profitable to borrow any government money, so the farmer's own capital is again fixed at the level of K_1 This is the case when the marginal value product curve turns out to be NMVP2 in Figure 7.1, and relevant internal return is R_1, not R_2. The same nature of the game is continued until $\lambda_i \geq R_i$ up to $K = K_1 + K_2 + K_3 + K_4$, where the latter two are again credit from private noninstitutional sources with different rates of interest.

Every reader will realize that the restirctions in Equations 7.10 - 7.14 are clearly fulfilled by this type of game. How about the restrictions in Equations 7.4 - 7.8? R_i's are some sort of market prices of capital and U_i are some sort of shadow prices for the constraints imposed. $[R_i + U_i]$ can be interpreted as the opportunity cost of each source of capital. Again, by the game played above, the internal rate of return, λ, in each region is greater than or equal to the opportunity cost, $R_i + U_i$. In other words, whenever λ is less than $R_i + U_i$, that source of credit is not used in the corresponding region.

Now we have proved that our solution satisfies all conditions imposed on our profit function. However, this does not necessarily prove that our solution is stable. But thanks to the facts that: (1) individual productivity coefficient is designated to be greater than zero and (2) the sum of these productivity coefficients is also less than unity, for each individual crop, as inferred from Chapter VI, the so-called second-order conditions automatically hold for this particular system.

Once the optimum rate of internal return (λ) for each region is determined, we are ready to project factor demand with Equation 7.27, in turn, to project yield levels with Equation 6.4.

When all these demand functions are substituted into the production function, the resulting function is called the supply function. However, we do not try to present the resultant equation here. Instead, let us compute some relevant variables involved. The reader may wonder how to compute the farmer's own capital used for farming and nonfarming, and capital borrowed from government sources, for example, when the marginal value product curves are NMPV1 and NMVP3, respectively. First, we compute the total expenditures, which are not weighted by area planted to each crop in each region such that:

$$7.37 \quad SVC_i(t) = \Sigma\Sigma PX_{i\ell}(t)\ FX_{ij\ell}(t)$$

where $PX_{i\ell}$ stands for input price and $FX_{ij\ell}$ for factor input levels used in the computer program, respectively, for $P_{xi\ell}$ and $X_{ij\ell}$. If this total expenditure, SVC, is less than the farmer's own capital available (FOK), that is:

$$7.38 \quad SVC_i(t) < FOK_i(t)$$

then we know that the farmer's own capital used for farming is SVC_i which is $K_1{}^*$ in Figure 7.1, and that for used nonfarming, $K_1 - K_1{}^*$, is $FOK_i(t) - SVC_i(t)$. Likewise, when:

$$7.39 \quad SVC_i(t) < [FOK_i(t) + GL_i(t)]$$

where GL is the government loan in computer program, K_2, then actually borrowed credit from government source, $K_2{}^* - K_1 = SVC_i(t) - FOK_i(t)$ and so on.

Let us try to understand the meaning of capital budget constraint used here, thereby, total expenditure, SVC. The concepts of these variables are somewhat different from common sense. Since we wnat to first determine the intensity of factor use per land unit, total expenditures represented by SVC are the sum of factor use per land unit over crops. Thus, the concept of the farmer's own capital, government loans, private loans types 1 and 2, represented by FOK, GL, PVL1 and PVL2, respectively, must be understood in that way. These variables can be obtained by: (1) dividing the total sum of capital available from each source by total cultivated area in each region, which is average capital availability per land unit and then (2) multiplying it by the total number of crops under consideration. The resulting amount of capital will be allocated to each crop.

Now, the reader has understood the basic methodology of factor demand projection. The only new fact thus far is that the capital market is incorporated, which puts the projections one step closer to the real world situation.

How should we deal with the problems originating with uncertainty or resource fixity to make the model much more realistic? One rough way to approximate this would be to introduce a distributed lag model for farmer's decision variables, such as prices or other relevant variables. The distributed lag model is introduced to economics to help study the decision-maker's behavior in making adjustments for problems stemming from uncertainty and resource fixity. The so-called "speed of adjustment" coefficient in the Nerlovian distributed lag model is nothing but the reciprocal of what we call average expected delay. Whenever all types of prices, PAVG for product, PX for input, and input level, FX, output level, YLD and interest rate such as GLIR for government, SVIR for salvage, PVLIR for private sources are used as the basis of the farmer's decision, the distributed lag variables rather than unlagged variables are used in the model. We already illustrated how to compute these distributed lag variables in Chapter IV.

On the other hand, it is often aruged that the magnitude of the elasticity of supply or factor demand is different, depending on the direction, duration and magnitude of the price change, for the consideration of uncertainty and resource fixity. At the same time, it is well widely known that the optimum input levels, hence, the output level with the Cobb-Douglas type of production function tends, to be overestimated [see Heady and Dillon (H.18)]. Therefore, derived elasticities of supply and demand also tend to be more or less exagerated [see Heady and Tweeten (H.19)].

When the sum of productivity coefficients, S_{ij}, or SALP in the computer program, approaches unity, it is not hard to see that demand elasticities approach infinity from Equation 7.33. This sum, SALP, in this study turns out to be around 0.2 - 0.3, owning to land and labor factors not being treated as variable inputs. Even in this situation, all elasticities exceed unity, which is hard to believe. We would have been much better off if we had been able to derive these elasticities from real world data. Due to a lack of appropriate data, which is especially common in the LDCs, we decided to approach from the other direction--a structural approach to the economic system and to show an alternative approach for facing a lack of data and exploring the existing body of economic theories.

Now, how do we incorporate uncertainty and the empirically observed tendency of factor demand to be more responsive to favorable than unfavorable prices in projecting factor demand? First, we hypothesize that the degree of regional specialization, the importance of a crop and the long-run profitability of the crop, play a role, respectively, in making the farmer's adjustment decision to price change. With this in mind, we again construct a sort of index of modify elasticities in Equation 7.33, based on suggestions by uncertainty. Figure 7.2 shows the relationship between the rate of change in the price level and the resulting index. This index compares the percentage of elasticities actually used to that computed from appropriate production coefficients. For example, if price is increased by 30 percent, the index turns out 0.5, which means the elasticity actually used becomes 50 percent of an appropriate coefficient of price change term in Equation 7.33. Note that this index varies depending on the size and direction of price change. Also, the distributed lag price is used to account for some degree of duration of price change.

More specifically, the demand elasticity with respect to product price, EFDPP, is modified as follows:[4]

$$7.40 \quad EFDPP_{ij\ell}(t) = ADFDE5_{ij\ell}(t) * [1.0 + ADFDE2_{ij}(t) + ADFDE3_{ij}(t) + ADFDE4_{ij}(t)] \,/\, [1.0 - SALP_{ij}(t)]$$

[4]Hereafter, notations used are those appearing in the computer program.

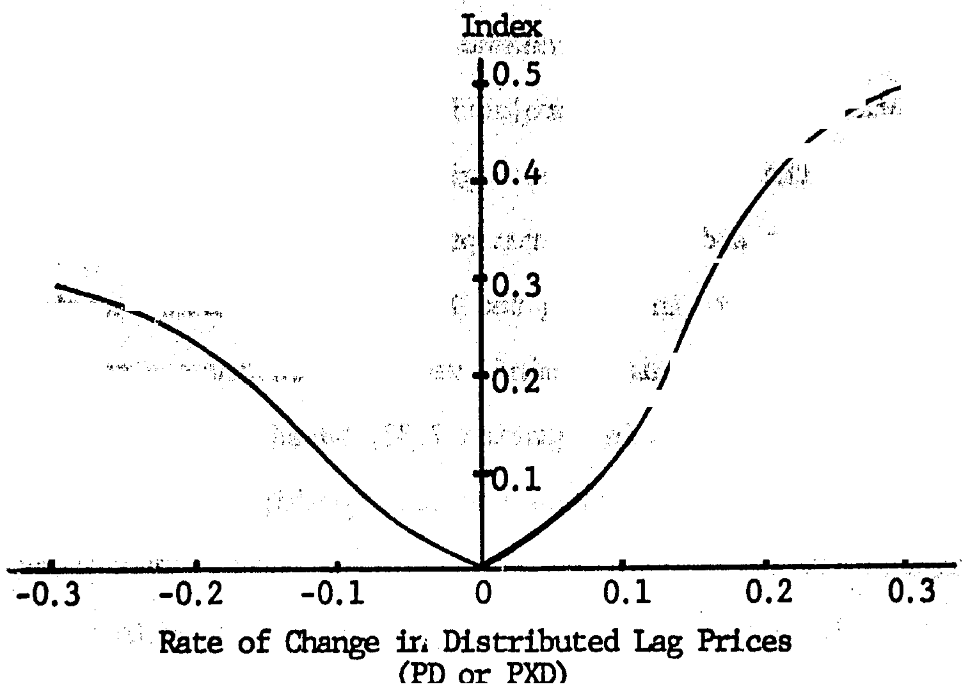

Figure 7.2. Index constructed to modify demand elasticities for factor, based on direction, magnitude and duration of price changes.

where ADFDE5 = index interpolated from Figure 7.2 based on product price change

SALP = sum of productivity coefficients

Note that demand elasticity with respect to product price derived from production function is 1 / [1 - $SALP_{ij}$(t)]. ADFDE2, ADFDE3 and ADFDE4 are some sort of adjusting factor for elasticities, based on the importance of the specific vrop (SZC), degree of regional specialization (RSP), and the long-run profitability (PROFTY), respectively. These independent variables are computed in Chapter V, and all dependent variables are then interpolated in the same fashion as before, using TABLE function. The rationale of the hypothesis that the degree of regional specialization, crop size and long-run profitability will affect the responsiveness of adjustment need not be explained in detail.

The demand elasticity with respect to own factor price, EFDOP, is then computed in the same manner:

$$7.41 \quad EFDOP_{ij\ell}(t) = ADFDE1_{ij\ell}(t) * [1.0 + ADFDE2_{ij}(t) + ADFDE3_{ij}(t) + ADFDE4_{ij}(t)]$$

where ADFDE1 is index computed from Figure 7.2, based on own factor price change.

Note that the rate of own price change term in Equation 7.33 has a coefficient of unity. All the cross price elasticities can be computed:

$$7.42 \quad EFDCP_{ij\ell}(t) = ALP_{ij\ell}(t) \ / \ [1.0 - SALP_{ij}(t)] * EFDOP_{ij\ell}(t)$$

where ALP is individual productivity coefficient, SALP is again the sum of the productivity coefficient ($\sum_{\ell} ALP_{ij\ell}$), and EFDOP is that computed in Equation 7.41.

Note that actual own price elasticity is spread into both Equations 7.41 and the rest in Equation 7.42. This is for technical and not economic reasons. Actually, own price elasticity is 1 + $ALP_{ij\ell}(t)$ / [1 - $SALP_{ij}(t)$], and what is called cross price elasticity is here computed from productivity coefficients as $ALP_{ij\ell}(t)$ / [1 - $SALP_{ij}(t)$], as seen in Equation 7.33.

Thus far, we have not made any statement about factor prices, including various interest rates. As noticed earlier, we use commodity price series projected under policy alternative 2 by the KASS temporarily until the model presented in this study is linked with other components. However, there are two intermediate products in this model that have no market prices for forage and grass from pasture. We have made tentative imputed prices for these two products, as the KASS did for other crops. Likewise, the KASS also has made a tentative projection for input prices. Since then, due to the energy crisis, the prospective on input prices turns out to be unfavorable to the agricultural sector, especially for fertilizer and pesticides, which require relatively more energy. More systematic projection of input prices would be a good topic for another Ph.D. dissertation.

In other to keep the study manageable, we adopted a simple assumption on input price change over time; the factor prices would be uniformly distributed random variable with the mean equal to the initial price level in 1970, and with a certain range (here 15 percent is assigned). That is:

$$7.43 \quad PX_{i\ell}(t) = PXP_{i\ell} + [R2(t) * PXBR_{i\ell} - 0.5* PXBR_{i\ell}]$$

where PXP; initial price of factors, R_2 is random number (1,0) generated by statement RANF(1), and PXBR is price change range, so that $[0.5*PXBR - PXP] \leq PX \leq [0.5*PXBR + PXP]$.

Similarly, the interest rate charged by government-supported financial institutions is assumed to be changed in the following manner:

$$7.44 \quad GL1RA_i(t) = RL1RB + [R1*GL1RR - 0.5*GL1RR]$$

Where GL1RB is basic government interest rate, GL1RR is interest rate change range, and R1 is random number [1,0] generated.

Product prices, factor prices and this interest rate are expressed in real, not nominal, terms. The government interest rate does not change year by year, but is fixed for several years once it changes What is the rationale behind the assumption of that being a random variable? A change in the real price of a commodity includes factors stemming from two sources: inflation and change in its nominal price. The real interest rate is, by the same token, a function of inflation, which is essentially assumed random here. So depending on the rate of inflation, the government interest rate may turn out to be negative, which is actually a form of subsidy. This can be usually evaluated ex post, not ex ante. Thus, the farmer's decision variable is assumed to be the distributed lag government real interest rate (GL1R), not GL1RA, as computed above:

$$7.45 \quad D * \frac{dGL1R_i(t)}{dt} + GL1R_i(t) = GL1RA_i(t)$$

Where D is the average adjustment time.

Then salvage interest rate of farmer's own capital ($SVIR_i$), and two private loan interest rates, RVL1R1 and PVL1R2, are assumed to be proportional to government interest rate.

There are some important related matters to be discussed at this point. First, capital supply. How can the farmer's own capital be determined? Clearly, the farmer's decision on consumption, saving and investment is closely interrelated, as Adams and Singh [A.3] point out. Nevertheless, a better specific mechanism is not known for the Korean agricultural setting. We adopted a simple mechanism. The farmer's own capital would be;

$$7.46 \quad FOK_i(t) = FOKPA * \Sigma\, YD_{ij}(t) * PD_{ij}(t) * \varepsilon^{FOKPX*t}$$

where YD and PD are, respectively, distributed lag yield and product price; FOKPX and FOKPA are parameters. That is, FOK is assumed a certain proportion of the long-fun gross revenue. This gross revenue is not weighted by acreage, so FOK can be used directly to compute the internal rate of returns.

Government loans are a policy variable partially, subject to farmer's needs. However, we tentatively assume here that government loan would be:

$$7.47 \quad GL_i(t) = GLPB_i * \varepsilon^{GLPA*t}$$

where GLFB is government loan in the initial year and GLPPA is the rate of growth. The two private loans are proportional to farmer's own capital supply.

Second, for national, regional average and total, we compute many different totals and averages for regions or the nation as a whole, in which the researchers and policy-makers are interested; however, we do not present the method of computation since they are mechanically computed using simple algebra.

Third, on units measured for factor uses and their prices. If each category of production factors defined in this study was composed of only one or several goods, each of which has the same element such as nitrogen, there would be no difficulty in measuring factor uses in terms of quantity, and market price could be used directly. However, even fertilizer is composed of factors supplying nitrogen, phosphorus, potash and lime. Even manure supplies almost all elements.

As there is no good common denominator for all these individual elements, the level of demand for them is expressed in terms of value used, and their prices are used to form an index. It is possible to convert values of factors used into quantites if we make an explicit assumption that the mix of individual factors will remain unchanged; for example, that the N K P mix remains unchanged over time. The following equation is designed to accomplish this job;

$$7.48 \quad FXQ_{ij\ell}(t) = FX_{ij\ell}(t) \; / \; PXB_{i\ell}$$

here PXQ is factor uses in terms of quantity, FX is factor uses in terms of value and PXB is weighted unit price of factors used for individual crop in the base year.

If one wants to project individual ingredients of fertilizer (FXEQ) after accepting above assumption, then we can compute:

$$7.49 \quad FXEQ_{ij\ell}(t) = FXEP_{ij\ell} * FXQ_{ij\ell}(t)$$

where FXEP stands for proportion of individual ingredients. However, we did not try to project this quantity at the present stage of model development, simply because we do not have enough data to compute PXB accurately enough.

Lastly, a criticism. After noting that the projected input and output rates by the optimization technique based on profit maximization assumption will be fed into the programming model of the farm resource allocation component of the KASS model, the reader may criticize that this is a double maximization procedure.[5] The

[5]This criticism is actually given by I. J. Singh through personal

production function in Figure 7.3 assumes that there are two production factors. First, note that there are infinite possibilities to combine two factors in producing the production level of Y_2, for example. The linear programmer would select a certain point, such as combination A, among the infinitive possibilities in the above figure to formulate his programming model. How would you interpret this particular combination of factors and output level? There are perhaps two possibilities: the combination A is interpreted as either the highest profitable combination or simply what farmers are doing. In the former case, can combination A or the resulting output level be interpreted as the highest profitable point, regardless of economic[6] and technological changes? Ruttan [R.9] calls the latter case the "requirement approach," which is clearly not the real world situation, and therefore again is criticized by Falcon [F.1]. Why does the linear programmer adopt a restrictive unrealistic assumption of this nature? A partial answer to this question was given in Chapter III.

A more realistic linear programmer will select several possible points of resource combinations along either iso-quant line or iso-cline line, such as A, B, C, etc., in Figure 7.3, and incorporate these combinations in his programming model. The linear programming algorism selects the highest profitable combination of activities under the

---

conversation at the beginning of conceptualization of the model. He and Byerlee at another time have suggested a programming approach to project input and output rates as an alternative.

[6]If some resources are subject to fixity, it is possible that the point can remain as the highest profitable combination in the short run.

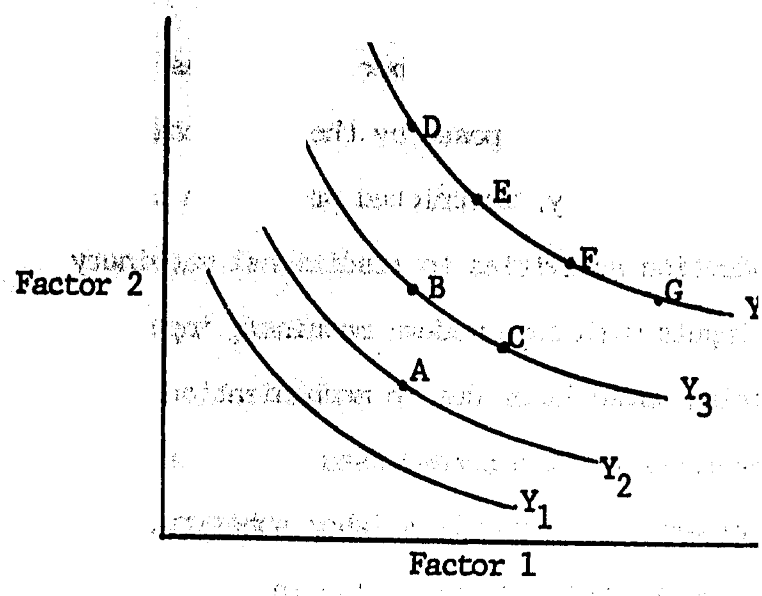

Figure 7.3. Iso-quants

given resource constraints to determine the optimum allocation and hence total production for the activities considered.

Why is this not called a double maximization, one maximization in selecting factor combination and another in selecting the acreage level? What is attempted in the present effort is to determine the optimum input levels, hence, output rates of each product under consideration, not in inside, but outside of the programming framework to give more opportunity to adjust to changes with more realistic constraints. A good housewife should be flexible enough to prepare some dishes in the kitchen while preparing steak on a grill outside and bring it all together at the table for an excellent meal for the family. A poor housewife knows only one way to cook, say, with a frying pan.

Labor Demand Projection Model

Let us turn to the projection of labor inputs. As indicated in Chapter III, the restrictions imposed by the other components of the KASS model are unfortunately, restricted projection of labor inputs for crop production activities to traditional machinery technology. Labor inputs with some modern machinery inputs can be computed by subtracting saved labor due to mechanization from labor inputs without mechanization. The needed assumptions are: (1) machinery under consideration is purely a labor substitute, which is probably correct enough to be of some value in understanding the real world situation, (2) labor inputs without machine inputs are not directly subject to economic change, which is rather restrictive, (3) labor inputs to be projected here are economic complement [Heady, (H.11, p. 194)] in one way, but not in both directions with the capital inputs.

This assumption needs to be explained further. Suppose we specify a production function as a function of two inputs, capital and labor. Furthermore, suppose our production function is of the Cobb-Douglas type. When the optimum input level of labor changes due to, say, a change in wage rate, other things being remained unchanged, the optimum input level of capital also changes in the same direction. The same phenomenon can be observed with a quadratic production function when the interaction term has a positive coefficient. On the other hand, Evenson [E.3] assumes the following production relationship:

$$7.50 \quad Y = f\,[f_b\,(X_b),\; f_m\,(X_m)]$$

where b denotes biological inputs and m mechanical inputs, including labor. What he really assumes is that both input categories are independent of each other. This is equivalent to saying that the interaction term in a quadratic function has zero coefficient. In other words, more fertilizer can be applied without using more labor, and increased production due to an increase in biological inputs can be harvested without increase in labor use, for example. This assumption would not be very restrictive if and only if the change in capital use is at its margin; however, under structural change, this assumption seems unduly restrictive.

Assumption 3 means that a change in capital input uses induce a change in labor use in the same direction, but not vice versa. With these assumptions, we hypothesize that labor use is a function of structural change in other input use. That is:

$$7.51 \quad FLB_{ij\ell}(t) = [1.0 + \Sigma\ FLBPA_{ij\ell} * FXR_{ij\ell}(t) + FLBPB_{ij\ell} \cdot YZD_{ij}(t) + \Sigma\ FLBPD_{ijk\ell} * SCR_{ik}(t) * ALLPA_{ijk} + FLBPC_{ij\ell} * ACTCR_{ij}(t)] * FLB_{ij\ell}(t)$$

where:

$FLB_{ij\ell}$ = labor use in each season for j^{th} crop in i^{th} region

FXR = the rate of change in other factor use

YED = the rate of change in total productivity

SCR = the rate of change in improved land

ACTC = change in tree crop age cohort

ALLPA = parameter indicating how improved land is allocated among various crops and all others are respective parameters having appropriate signs

Total labor used for producing a crop may be also a worthwhile project. For this, we use a simple mechanism after adopting the assumption that labor use for other than the seasons considered here will change proportionally to the sum of labor used for the seasons considered. That is:

$$7.52 \quad TFLB_{ij}(t) = TFLBP_{ij} * [FLB_{ij1}(t) + FLB_{ij2}]$$

Where

TFLB = total labor used for producing a crop in a region

TFLBP = a constant parameter

In summary, we have modeled a factor demand relationship in this chapter. Because of data gaps, we have used the factor demand function derived from a production function for projecting factor demand. The derived factor demand elasticities generally tend to be overvalued. Thus, we have adjusted the elasticities, depending on the direction, duration and magnitude of price change. As will be discussed in Chapter IX, the adjusted elasticities seem to be undervalued. However, when parameters of factor demand function that are more realistic become available, we can easily use these better estimates in place of those derived from the production function. Further studies needed for other structural relationships will be discussed in Chapters IX, X and XI.

PART III

BASIC RESULTS AND SENSITIVITY TESTS

PART III

BASIC RESULTS AND SENSITIVITY TESTS

CHAPTER VIII

MODEL VALIDATION AND SENSITIVITY TESTS

Introduction

Now that we have completed the necessary mathematical models based on relevant useful theories, it is in order to present the basic results of the model projections; however, we need ask ourselves whether or not the model works properly and has the necessary objectivity properties for policy recommendations.

This part deals with four distinctive subject areas: model validation, sensitivity tests, public investment management or project implementation, and policy experiments. The sensitivity tests are undertaken for two basic purposes: to examine whether or not the model is internally consistent and works properly--one part of model verification--and at the same time, to examine which parameters are most and least important in determining the basic major output variables to guide the further study of the model structure itself and on data improvement. The project management or implementation, another type of sensitivity test, is examined in terms of annual budget allocation for a given long-term plan. Project completion is often subject to changes in annual budget allocations. In other words, we need to examine the possible consequences of prolongation of project implementation due to changes of actual from planned investments. Chapter VIII discusses these three matters.

Chapter IX deals with still another type of sensitivity analysis--policy experiments. The former sensitivity test focuses on the model parameters, whereas the latter one is designed to determine what happens to model outputs or the performance variables when different values are assigned to the policy variables. The primary purpose of these policy experiments, of course, is to derive a set of policy recommendations that are more desirable in view of development goals. While the policy runs of Chapter IX give useful insights into model behavior and validity, policy implications drawn from them at this time should be carefully qualified. Use of the model in aiding decision-makers can only come after further model and data refinement.

In both chapters, we present results graphically, if possible However, as there are many relevant response variables, it is sometimes very complicated, if not impossible, to present the results graphically. In this situation, we will use either tables or figures for key response variables only.

As stated in the text, one of the major purposes of having any sensitivity test is to determine if a model works properly. As the test proceeds, inconsistencies, defects, etc. are continuously found and corrected. It would be more or less ideal to repeat all sensitivity tests and present their results after the model is completely refined. However, model refinement is an endless process from mathematical modeling to model application. For this reason, in addition to several other considerations such as budget and time constraints, etc., we did not run the previous runs again, even if after changing the model structure, parameters, etc., in the process of the sensitivity tests, when we do not expect that our major conclusions are seriously affected by these changes.

This chapter is divided into three sections. In section one, after briefly surveying methodologies of validation or evaluation of simulation models, we will discuss the procedure used in the present study for validating the model. Then, in section two, we will present some results of the sentitivity tests on selected major model parameters. The last section is devoted to sensitivity analyses in the process of project implementation.

Model Verification

The terms "model verification" and "model validation" are used interchangeably here. What do we mean by verification or validation? According to Naylor and Finger [N.4, p. 153-154],

> "To validate any kind of model means to prove the model to be true. But to prove that a model is 'true' implies (1) that we have established a set of criteria for differentiating between the models that are 'true' and the models that are 'not true,' and (2) that we have the ability to readily apply these criteria to any given model."

In another paper, Naylor [N.3] insists that "The validity of an econometric model (simulation model) depends on the ability of the model to predict the behavior of the actual economic system on which the model is based." This is essentially the positive economics approach discussed by Friedman. Then he continues, "in order to test the degree to which data generated by simulation experiments with econometric models conform to observed data, two alternatives are available--historical varification and verification by forecasting."

Is this methdology universally applicable to any model? If not what alternatives are available?

Kresge [K.8] states that:

> "As applied to development planning, simulation analysis is as yet more an art than a science. . . Generally there is very little data available for either the estimation or evaluation of the simulation model. The bits and pieces of information which are available are at best incomplete and, only too frequently, are inconsistent as well."

Thus, he seems to think it is inevitable that any model of development planning involves "a rather impressive act of faith. . ." and simulation analysis should be judged in a pragmatic fashion.

Holland [H.26] maintains a similar position, by saying that:

> ". . .imagine trying to verify that relation which is the innovation diffusion process of MSU Nigerian model (M.4) and estimate its parameters! If experienced observers believe this is the way things really work, that is the way they should be in the model, even if the parameters cannot be measured."

Halter, et al. [H.2] seems to basically agree with Naylor's position concerning model validation. They put it this way:

> ". . .validation of a complex simulation model is by no means an easy task but certainly is of key importance if a model is to be used for decision making. If the model describes an existing system, it is sometimes possible to rigorously compare the behavior of the model with the past behavior of the real world system and thereby gain insight into model validity."

However, they seem rather pessimistic when it comes to what Naylor calls verification through prospective predictions and a model that describes a system that does not exist, such as development planning. They claim that "the latter method (verification by forecasting) involves a waiting period that may be intolerable in the situation at hand."

For the case of development planning, they state:

> ". . .if the purpose of the model is to help plan a system that doesn't exist, the problem of validation can be even more formidable. In this case, validation hinges on the laws, assumptions, and logic embedded in the model and can be viewed as 'validation by deduction'. It's encouraging to note here that models have been useful in the design of new systems in many areas of activity. In any event a simulation is never more than an approximation of reality. The question that must be answered is: Is the model an acceptable approximation?"

Holland H.26 raises another issue. According to him,

> "Another topic on which the two papers Naylor (N.3) and Halter, et al. (H.2) seem to agree--up to a point--is on validation of models. Both speak of matching historical data and verifying forecasts, judging the validity of the model by the fidelity with which it matches observed data. But this sort of validation is not sufficient; it misses a crucial point. The most important requirement of a simulation that is to be used for policy experiments is that it should respond correctly to changes in the policies at issue. For this purpose, it is important that the mechanisms involved in the response should be right qualitatively as well as sufficiently accurate numerically. If similar policy changes have not occurred in the past, then matching past data is no indication that the response to policy change will be properly simulated."

There seems to be some confusion about a large-scale simulation model. What do we mean by a large-scale simulation or econometric model? What are its main characteristics? Suppose a system of equations for simulation purposes has been simultaneously derived from historical data, including exogenous variables such as policy variables. Why do we need historical verification? Should we not regard the model as verified when a system of equation is estimated? It seems that the validation problem in terms of historical verification arises because the system of equations has not been estimated simultaneously; instead all or some equations have been estimated separately.

This seems to be one of the main characteristics of a large-scale simulation model.

Whether the system of equations has been estimated simultaneously or separately, how do we interpret the general thesis that regression analysis of time series data is an imperfect tool for supply prediction in the presence of technological or structural change, which we discussed at length in Chapter VI? In the process of economic transformation, the estimated parameters themselves are likely unstable, and moreover, as Nelson [N.5] makes clear, there is an important interaction among and between input uses and so-called technical change. If this is the case, and if we talk about economic development planning, how much weight should we give to historical verification for validating a model intended to represent a system under structural change?

It seems that, as Naylor [N.4, p. 21] points out, the problem of validating simulation model is indeed a difficult one, since it involves a host of practical, theoretical, statistical and even philosophical complexities. This difficulty is not confined to simulation models only. Instead, validators of any kind of model or hypothesis seem to confront the same problem. Naylor and Finger [N.4, Ch. 5] outline procedures for validating a simulation model historically.

Having concluded that it is impossible to establish either the truth or falsity of any empirical theory or model, Shapiro [S.7] outlines some descriptive measures, which, he thinks, are useful in assessing the forecasting performance of econometric models.

How should we handle this difficult job, especially when we have a very limited amount of data, which is incomplete and inconsistent? One way to answer this problem is to find out how other researchers handle this subject. Manetsch and Park [M.6, Ch. 1] feel that validation is an extension of viability testing. If the mathematical model is to be used to design a system that does not yet exist, model validation does not exist in terms of historical verification and verification by forecasting. In this case, what we can do, they think, is to carry out exhaustive viability testing to ensure that the model satisfies necessary conditions for validity.

What do we mean by a viability test? As a preliminary phase of model validation, viability testing is intended to determine whether or not the constructed model meets a certain fundamental requirement for validity; that is, whether or not variables have the correct sign, behave appropriately, lie within known bounds, etc., according to Manetsch and Park [M.6, p. 32].

This methodology basically seems to rest on a particular philosophy of science-rationalism. In fact, Mitroff and Turoff [M.19] discuss five methodological positions of science in connection with technology forecasting and assessment. These positions are represented by: (1) Leibnitz (rationalism), (2) Locke (empiricism), (3) Kant (synthetic), (4) Hegel, and (5) Singer (pragmatism). They then discuss which philosophical position is best suited to the situation. That is, a particular position is not necessarily the best methodology for every situation. For example, in designing a space ship, the Leibnitzian inquiry system is the only one available, and in forecasting a well structured and stable system, the Lockean inquiry system is certainly a suitable position.

According to Mitroff and Turoff, Kantian and Hegelian inquires are best suited to problems that are inherently ill-structured; problems that are inherently difficult to formulate in pure Leibnitzian or Lockean terms, either because their nature does not admit of a clear consensus or a simple analytic attack or because the true nature is not well known. They feel that "Singerian inquirers are the epitome of synthetic, multimodel, interdisciplinary systems. In effect, Singerian inquiry constitutes a theory about all the other inquires, and forms a theory about how to manage their application." They believe that "Singerian inquiry is virtually absent from the field of technological forecasting and assessment," but think that "the strength of Singerian inquiry is that it gives the broadest possible modeling of any inquirer on any problem."

Johnson [J. 16, Ch. 4] advances an evaluative method for a model or thereby derived policy prescriptions. The philosophical or methodological basis of this method is given in Johnson and Zerby [J.15, Ch. 1 and 6]. This method appears to have been applied to subsequent works by Johnson and his associates [J.16, R.7, M.15, M.18, P.6, etc.]. This method uses four "objectivity tests." It seems to be an eclectic method, in the sense that it is not based on a single scientific philosophy. In other words, this method recognizes the strengths of several philosophical positions such as positivism or empiricalism, normativism, pragmatism, existentialism, etc., in solving practical problems.

The essence of this objectivity or credibility test can be shown by quoting Johnson [J.16, p. 46]:

> "To establish that a concept is objective is to show that it (1) has a clear and specifiable meaning, (2) is consistent with other acceptable concepts, laws, and theories, and (3) is useful in solving the problems with which one is confronted."

The first criteria, known as the "clarity test," rests heavily on Kantian inquiry systems. The second is the "consistency test," which is based on both Lockean and Leibnitzian inquiry systems, and the third is the "workability test," based on Singerian and Hegelian inquiry systems.

Since the present study relies heavily on this objectivity test for model validation, it would be worthwhile to examine this method in detail. The reasons the present study adopts this particular method for model validation have been discussed implicitly above. In addition to data gaps, the system under consideration in this study is supposed to be changed in terms of parameters and the system structure itself, because the system is in process of transformation from one structure to another. This is, essentially, one that a development policy intends to achieve. This does not mean that a positivistic historical verification is not useful, but it has some shortcomings. It is merely a necessary step to infer whether a model works properly and must be used along with viability tests sensitivity tests, and other tests suggested above.

The test of consistency is both internal and external, according to Johnson. Internal consistency is a logical or analytical matter and requires that a set of concepts bear a logical relationship to each other whether they pertain to the past, present, conditional or unconditional future. The external consistency test is the test of experience, which includes consistency with synthetic concepts derived from experience as well as analytic concepts deduced logically from propositions. The test of clarity is established when a concept can be communicated between people without ambiguity or vagueness. The test of workability as a pragmatic approach is established when a concept is useful for solving a practical problem. This test is closely related to the external consistency test, while the clarity test is related to the internal test.

Let us see how this evaluative method has been used for validating systems simulation models. Good examples are found in the Nigerian model [M.15] and the Venezuelan cattle industry model [M.18]. In a recent article on the Nigerian model, it is made clear that it is inevitable to use data from a variety of sources for a large and complex model, and data gaps are filled with knowledgable estimates from researchers, extension people and other informed personnel. Then, the process of the model validation starts and continues. That is, each subcomponent model with these initial estimates of parameters and initial conditions is run in a computer to detect errors. Subcomponent output is then evaluated using appropriate theory, dynamic systems concepts, and the relationship of the simulated values to historical data and expected future values. Where inconsistencies or abnormalities are noted, the problem is diagnosed, changes made, and testing continued. Many sensitivity runs are done to test the impact of possible errors in specific model parameters, and to infer needed additional data or structural equation modification.

After emphasizing that simulation model development and validation are iterative processes of problem solving, Miller and Halter [M.18] used three tests for model validation for the Venezuelan cattle industry. They suggest that

> . . .insight can be gained into the validity of the model by checking the logic of the model, by comparing computer results with historical data and by assessing the model's predictive ability from a theoretical and/or common sense standpoint."

Let us now consider how to validate the model presented in this study. One thing clear from the above discussion is that we need some sort of historical verification for major model outputs as a part of the model validation process, although it may not fulfill perfectly either the necessary or sufficient conditions for validating the models. We must have at least three additional sets of variables; all initial conditions, policy inputs in past history, and all other exogenous variables, including variables computed in other components of the KASS model. This job will require considerable time, in addition to the problem of reasonably accurate data.

Data used in the model in its present stage of development are tentative. This implies that, first of all, data or information on which technical and behavior coefficients and initial conditions are based need to be improved before undertaking historical tracking or making policy prescriptions. We will address the data problem again in a later chapter. At any rate, the present study is continuous and has an iterative property in the sense that problem definition, modeling, model refinement and application are all interactive with feedback to each other.

What can we do about model validation? The channels open to us at the present stage of the model development are: (1) internal consistency test, (2) external consistency test, (3) clarity test, and (4) workability test. As indicated above, building a simulation model is iterative. This means that some of the indicated tests have already been done, some will be done in the process of preparation for the following sections and chapters, and still others will be done whenever specific model application is needed.

Sensitivity Analysis

In this section, we will present some results of sensitvity analysis on the combined total model. The purpose of undertaking this analysis is implicitly stated above. As a matter of fact, sensitivity analysis of the total model has several useful functions in the overall model-building process. More specifically, according to Manetsch, et al. [M.4], there are three major functions sensitivity analysis can perform. The first and most important function is to help understand the behavior of the model and check its logical consistency. In other words, this analysis acts as a part of model validation. Second, sensitivity analysis helps in exploring the various policy implications of the model. Lastly, sensitivity analysis is useful in pinpointing further data requirements of the model.

On what kinds of data should we make the sensitivity tests? The purpose of this test has already implied the kinds of parameters or data to be included in the test. Since we will concentrate on sensitivity analysis on policy variables in the next chapter, we will present the results on other variables in this section. Parameters or data for the present purpose can be put into three groups: (1) behavioral parameters, (2) technical coefficients, and (3) initial conditions. Since there are a large number of parameters or data in each of these categories, we must include only a few in order to make the analysis manageable. The data base of the model at the present stage of development is poor, and almost all of the data are rather tentative. Moreover, a set of data is related to other sets of data in governing the model behavior. This sort of interaction among parameters through behavioral equations of the system implies that the sensitivity analysis will bring more useful information when and if the overall data base has been improved to some degree.

There is another difficulty in this analysis. That is, there are many output variables, intermediate or final. One parameter may significantly affect one variable, but not affect others, or an intermediate variable but not a final variable. There is another difficulty, too. Almost all parameters are subscripted by region crop, land and water development project, etc. It would be inconvenient to test individual elements of a parameter set. On the other hand, it would not be appropriate to treat a parameter set as a set.

Despite these difficulties, we analyze several sample parameters or data from each main subroutine, as shown in Table 8.1, and variable names will be explained again.

Let us discuss the results of sensitivity analysis by subroutine. $APSC_{ik}$ is defined as unit cost of land and water development

Table 8.1. Parameters or Data to be Varied in Sensitivity Tests.

	Land and Water Development (PUBINV)	Research and Extension (SOCDIF)	Factor Demand and Product Supply (FDYLD)
Initial Condition			YLD(I,J)
Behavioral Parameter		AEEA AMTA DFC DGAM RRFA RRFM	FOKPX
Technical Coefficient	APSC(I,K)		YLDPA(I,J,K) ASC1(I,J,K) ASC2(I,J,K) ASC3(I,J,K) FLBPD1(I,J,K) FLBPD2(I,J,K) ALP(I,J,K)

project k in region i. This variable is assumed to be a function of time and the accumulated improved area. What is of interest here is the value of function intercept or unit cost in the beginning year. Thus, we assigned 20 percent higher and lower values to the orginal value of this parameter. Total accumulated area for the large-scale irrigation project in region 1 (TL_{13}) has been selected to analyze the possible impact of these changes. The result is given in Table 8.2.

With a given total project budget, it is expected that improved area will be increased when unit cost is smaller, and vice versa. However, the impact may not be symmetrical with respect to direction, due to model structure. This relationship is shown in terms of structural elascicity in Table 8.2. The term "structural elasticity" as used by Kelly, et al. [K.3, p. 178], is defined as a ratio of percent change in response variable to percent change in input variable as usual.

Table 8.2. Structural Elasticity of Accumulated Area of Large-Scale Irrigation Project in Region 1 with Respect to Unit Cost in Selected Years.

Relative to Basic Value	1975	1980	1985
0.80	-0.371	-0.655	-0.782
1.20	-0.245	-0.439	-0.526

AEEA has been defined as a parameter that governs the input rate of land to the delay process of innovation diffusion due to promotion (extension) in each year. GZS has been selected as a response variable to be analyzed in terms of rice in Region 1. GZS is defined as the accumulated expected yield increase in percentage due to research and extension.

Table 8.3. Accumulated Expected Yield Increase Due to Research and Extension, GZS, Rice in Region 1, By Different Values of AEEA, 1 Selected Years.

Value of AEEA	GZS		
	1975	1980	1985
0.015	10.08	28.65	46.66
0.025	10.55	29.17	46.70

GZS is not very sensitive to change in value of AEEA. This parameter, like others, interacts directly or indirectly with other parameters or variables. Thus, it might be better if we could analyze it by using factorial design.

Parameter AMTA has the same property as AEEA, but is supposed to determine land input rate due to diffusion rather than due to promotion.

As seen in Table 8.4, there is no difference in GZS for different values of AMTA, in these particular years for this particular product, rice. But we have made sure that there exists some effect on other products and even on rice at the other points of time.

Table 8.4. Accumulated Expected Yield Increase Due to Research and Extension, GZS, Rice in Region 1, by Different Values of AMTA, in Selected Years.

Value of AMTA	GZS		
	1975	1980	1985
0.3	10.08	28.65	46.66
0.5	10.08	28.65	46.66

Parameter DFC is designed to discount the effect of transition relative to modern land on determination of diffusion effect, productivity increase, etc. As seen in Table 8.5, there is not much difference in GZS for different values of DFC.

Parameter DGAM is defined as the maximum number of years for expected average delay in innovation diffusion in the case when no stimulatn is given. As shown in Table 8.6, the effect of changing the value of this parameter can be said to be negligible within the range shown in the table.

Table 8.5. Accumulated Expected Yield Increase Due to Research and Extension, GZS, Rice in Region 1 By Different Values of DFC, in Selected Years.

Value of DFC	GZS		
	1975	1980	1985
0.8	10.08	28.65	46.66
0.4	9.62	27.25	45.65

Table 8.6. Accumulated Expected Yield Increase Due to Research and Extension, GZS, Rice in Region 1 By Different Values of DGAM, in Selected Years.

Value of DGAM	GZS		
	1975	1980	1985
11	10.08	28.65	46.66
15	9.99	28.62	46.61

Parameters RRFA and RRFM are defined, respectively, as a parameter to determine the dropout or reject rate after trying new biological technology, and a parameter specifying a maximum reject rate. However, there is not much change in GZS in each case when RRFA is varied from 0.05 to 0.08, and RRFm from 0.1 to 0.3. Thus we will not present them here.

The greatest influence on the output variables is from initial conditions, especially, yields. This is because of the particular form of yield projection equation. That is, the current yield level is computed by multiplying the previous year's yield with a desired rate of change. To see the possible impact, we assign 20-percent higher values to all initial values relative to the basic value.

As expected, a 20-percent increase in the initial yield level results in a 20-percent increase in any subsequent year's yield, as shown in Table 8.7.

Table 8.7. Expected Yield Level of Rice (National Average), by Different Initial Conditions of Rice Yield, in Sel[illegible] Years (Ton/Ha).

Relative Initial Conditions	Rice Yield		
	[illegible]5	1980	1985
1.00	[illegible].365	3.881	4.197
1.20	4.289	4.669	5.041

Parameter FOKPX is a parameter governing the consumption, hence, the farmer's own capital for use in the following year. This parameter is not an average or margional propensity to save, but instead, a factor shifting the saving function, as shown in Equation 7.46. The effect of changing this parameter is shown in Table 8.8.

At any rate, average yi[illegible]ld level does not seem to be affected very much by this parameter alone.

$YLDPA_{ijk}$ is a kind of yield elasticity with respect to change in structural variables, other than those concerning variety changes and new land development. The possible impact of varying this parameter on the response variables are shown in Table 8.9. As expected, the yield level is certainly influenced by a change in this parameter Hence, all other response variables are also changed.

Table 8.8. Expected Yield Level of Rice (National Average), by Different Values of FOKPX, in Selected Years (Ton/Ha).

Value of FOKPX	Rice Yield		
	1975	1980	1985
0.02	3.565	3.881	4.197
0.05	3.571	3.879	4.186

Table 8.9. Impact of Varying Value of YLDPA on Selected Response Variables, in 1985[1].

Response Variable	Unit	Value of YLDPA Relative to Initial Value	
		1.0	1.5
Average Rice Yield	Ton/Ha	5.825	5.948
Total Rice Production	Million ton	7,336	7,491
Total Grain Production	Million Ton	13,415	13,576
Total Value Added	Billion Won	1,361	1,377

[1]All four runs hereafter are based on the medium policy level set, which will be discussed in Chapter IX.

Parameters $ASC1_{ijk}$, $ASC2_{ijk}$ and $ASC3_{ijk}$ are again demand elasticities for factors 1, 2 and 3, respectively, with respect to structural variable change as defined above. The possible impact of varying these parameter values is shown in Table 8.10. There is no change at all in grain production due to changes in values of these parameters. This conclusion was to be anticipated, since elasticity represents ad in Figure 6.1, whereas the pure effect of structural change on yield level is ab. In order to avoid double-counting, we subtracted the effect of factor use change from the gross effect of structural change, as illustrated in Equation 6.14. However, for a certain land and water development project and for a certain crop, it is assumed that the structural change variable has no direct effect on increasing yield, but has an indirect effect. That is, structural change is assumed to induce a change in factor use, for example, in barley production through, say, land consolidation. However, this effect seems to have been negligible since these parameters have relatively smaller values, and the magnitude of structural change variables is also rather small over time. Nevertheless, a change in the value of these parameters affects demand for factors and hence, total material costs, and in turn, total value added, as seen in Table 8.10.

Table 8.10. Impact of Varying Value of ASCs on Selected Response Variables, in 1985.

Response Variable	Unit	Value of ASCs Relative to Initial Run	
		1.0	0.5
Average Rice Yield	Ton/Ha	5.825	5.825
Total Rice Production	Million Ton	7,336	7,336
Total Grain Production	Million Ton	13,415	13,415
Total VAlue Added	Billion Won	1,361	1,363
Total Material Costs	Billion Won	187	184

The parameters, FLBPDs, are defined as labor demand elasticity with respect to structural change. The possible impact of changing the values of these parameters is shown in Table 8.11. As expected, a change in the value of these parameters does not affect physical production and value added, due to the model assumption made. However, an increase in this parameters results in a greater reduction in total labor demand. It should be remembered that land and water development (except for new land) reduces labor demand.

Table 8.11. Impact of Varying Values of FLBPDs on Selected Response Variables in 1985.

Response Variable	Unit	Value of FLBPDs Relative to Initial Run	
		1.0	1.5
Average Rice Yield	Ton/Ha	5.825	5.825
Total Value Added	Billion Won	1,361	1,361
Total Labor Demand	Million Hrs.	5,085	4,639

The last parameters we want to examine are productivity coefficients of the so-called conventional inputs, ALP. As the reader may remember, these coefficients are assumed to be equal to the respective factor shares. These coefficients computed in this way may not reflect the real world situation. Thus, we have decided to examine what happens if the magnitudes of these coefficients differ from those computed. The results are shown in Table 8.12. Surprisingly enough, there is not much difference in average yields and hence, total grain production among different values for these coefficients.

Table 8.12. Impact of Varying Values of Productivity Coefficients, ALPs, on Selected Response Variables in 1985.

Response Variable	Unit	Value of ALPs Relative to Initial Run		
		0.5	1.0	1.5
Average Rice Yield	Ton/Ha	5.82	5.83	5.84
Total Grain Production	Million Ton	13,146	13,415	13,429

There are two major uses for these productivity coefficients in our system. The first is to influence the demand for conventional inputs in response to a change in the price level. This run is based on the medium policy level set discussed in the next chapter, where we assume factor prices are constant and product prices change slightly. Therefore, there is little room for these coefficients to play a role. The second use is, of course, to compute yield responses to changes in conventional input use. As we will see in Chapter X, the rate of change in these conventional inputs are rather small. Thus, the yield response and hence total grain production turn out to be relatively insensitive to changes in the values of these productivity coefficients.

In summary, what conclusion can be drawn from this analysis? We do not intend to conclude which parameters are sensitive and which are not. As indicated earlier, the data base is poor, data are related to each other, and we have not examined all relevant response variables, some of which may have opposite effects from others. Before leaving this section, we conclude that: (1) the overall data base must be revised based on the real world situation before conducting useful policy experiments or other projections and (2) very essential aspects validation and verification are not covered by sensitivity tests internal consistency, clarity and workability tests have not been directly presented here. We made sure that these tests are used in doing the analyses to be presented in what follows. In other words, while conducting sensitivity tests, we found that not all the relevant variables responded appropriately to changes in parameters and input levels. Whenever there is no good reason for this inappropriate response, we have diagnosed the relevant part of the system model by printing out all relevant variable values. After finding errors in the model structure or in parameters, we have corrected these errors until the model has worked properly. This process was repeated until all policy runs (which are the subject matter of the next chapter) were completed.

Land and Water Development Project Implementation

It usually takes more than one year for completion of a land and water development project. This implies a need for long-run planning. On the other hand, the implementation budget is typically determined on an annual basis, which, in turn, implies that the annual implementation budget is subject to revision because of political, economic and other factors. In this situation, the actual budget allocated to a specific project is likely to differ from the one that would bring about maximum efficiency. This, in turn, causes the initiated project to remain incomplete beyond the normal gestation period, which implies social losses. This section deals with consequences of alternative patterns of annual budget allocation for project implementation.

We distinguished three different budgets in Chapter IV: the intended budget (long-run) determines the rate at which land enters the project implement process, the desired budget is that needed to implement a project already initiated, and the actual budget is the budget actually allocated by government. It may be well to suppose that we can get efficiency when and if the actual allocated budget is equal to the desired one.

What will happen if the actual budget is not allocated in such a way? If an initiated project is never completed, the costs for initiation are a social loss. Shortage of an actual budget relative to that desired means that at least some individual projects must remain incomplete and prolongs the gestation period. This extension of the implementation period, in turn, requires an increase in the desired implementation budget (see Equations 4.6 and 4.24). The reason is given in Chapter IV, where Equation 4.20 is formulated. In other words, unit cost is a function of time as well. The expected average time for project implementation now becomes a function of the actual budget allocation. As the actual budget relative to the desired one becomes smaller and smaller, the expected average time for implementation in aggregate becomes longer and longer. This increases the desired budget. It is a vicious circle.

This vicious circle of poverty is analyzed by Manetsch [M.7] who applies a time-varying delay subroutine, VDEL. However, as we have seen earlier, we use DELLVF subroutine for the reason given in Chapter IV. With this much reorientation for using DELLVF subroutine, let us discuss the result of analysis. First, the assumptions about the behavior of the actual budget relative to the desired one should be made clear. The intended investment may go high in a certain year, such as a general election year. In the following year, the desired investment goes up. For this or other reasons, the actual investment falls relative to the desired one. In a certain year, such as the year before a general election, actual investments may exceed the desired level. In short, actual investments may fluctuate below and above the desired investment. This fluctuation may differ depending on kinds of projects, economic, social or political stability, the long-run production prospect or other factors. Here, we adapt a simplified assumption about the behavior of actual relative to the desired investment. That is, we want to examine the possible consequence of project implementation when the actual investment is (1) 60, (2) 80, (3) 100, and (4) 120 percent of the desired investment throughout the planning horizon.

How does this different rate affect the expected average delay time of project implementation? In Chapter IV, we assumed the expected delay, DEL(I,K), in Equation 4.5 to be constant. However, to examine the consequence of divergency between actual and desired investment, we need the expected project delay time (DEL_{ik}) to be a function of the ratio discussed above. This is computed as follows:

$$8.1 \quad DEL_{ik}(t) = DELPP_{ik} * DELPA_{ik}(t)$$

where $DELPP_{ik}$ is a constant reflecting average delay time required for implementing project k in region i when the budget is allocated ideally, and $DELPA_{ik}$ is a factor reflecting an effect of the divergency on the average delay time, and computed by the TABLE function:[1]

8.2 DELPA(I,K) = TABLE [VALA, SMALL, DIFA, KA, RATDB(I,K)]

where $RATDB_{ik}$ is the ratio of actual to desired investment for project k in region i, and SMALL, DIFA and KA are necessary parameters for interpolation.

$VALA_{ik}$ is function value of $DELPA_{ik}$, depending on the magnitude of $RATDB_{ik}$, and has the shape shown in Figure 8.1. Now we are ready to apply the DELLVF subroutine since $DELDP_{ik}$ is simply one time period lagged DEL_{ik} and other parameters in Equation 4.5 are already given. But we need to explain assumptions underlying the above figure. The corresponding function value when the ratio is 0.5, for example, is 2.5. This means that when the actual investment made is half the desired one, the expected delay time will be extended by 2.5 times the normal delay time.

Some of the results of this analysis, based on the above assumptions, are presented in Tables 8.12 - 8.17. It is necessary to keep one thing in mind in interpreting the results: there are some projects under implementation process (storage) at the beginning and the end of the planning horizon. At any rate, let us assume that storages at the beginning and end would cancel each other out or the difference would be negligible. Table 8.12 presents total accumulated land areas improved by various projects until 1985, depending on the ratio of

---

[1]For a technical reason, DELPA is computed separately for a case where RATDB is less or equal to one from a case where the ratio is greater than one.

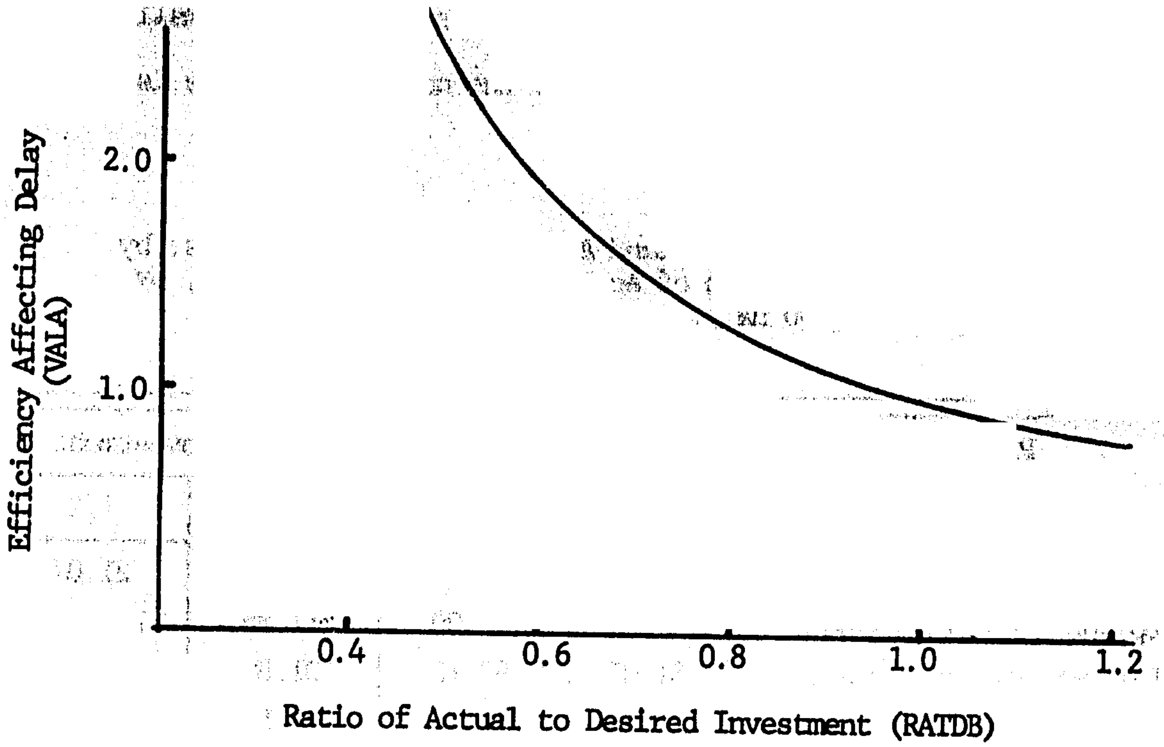

Figure 8.1. Relationship between ratio of actual to desired investment and efficiency affecting delay time for project implementation.

actual to desired investment. At least three points are worthwhile noting from this table. First, the improved land area is not proportional to the ratio. Second, the rate of change in the improved land area is different, depending on the direction of change in the ratio. For example, in the case of tideland development, when the ratio is 0.8, the improved area is 94.5 percent of the normal case where the ratio is 1.0, whereas the improved area is 101.5 percent when the ratio is 1.2. Third, the improved land area is also different, depending on the length of the normal delay time and possibly on also the order of the delay. For example, when the ratio is 0.8, the improved land for the large-scale irrigation project is 95.4 percent of the normal situation (normal delay is 2.5 years), whereas that for the small-scale irrigation project is 97.3 percent where the normal delay time is 1.5 years.

Table 8.13. Total Accumulated Land Areas Improved by Projects, by Different Ratios of Actual to Desired Investment, by 1985 (1,000 ha.).

Project	Ratio of Actual to Desired Investment			
	0.6	0.8	1.0	1.2
Tideland Development	17.12	19.69	20.75	21.07
Upland Land Development	190.39	206.00	211.36	213.23
Large-Scale Irrigation	81.07	97.16	101.89	102.70
Small-Scale Irrigation	127.40	138.75	142.57	143.44
Paddy Consolidation	306.18	322.16	329.01	330.99
Paddy Drainage	80.33	83.67	84.63	84.93
Upland Consolidation	207.63	214.91	217.39	218.15
Upland Irrigation	226.04	237.82	242.87	244.33

Table 8.14. Total Accumulated Land Area Under Implementation by Projects, by Different Ratios of Actual to Desired Investment, by 1985 (1,000 ha.).

Project	Ratio of Actual to Desired Investment			
	0.6	0.8	1.0	1.2
Tideland Development	107.07	80.70	66.64	61.85
Upland Development	755.78	548.03	444.38	410.78
Large-Scale Irrigation	348.01	273.81	226.71	209.97
Small-Scale Irrigation	345.68	251.96	204.91	189.28
Paddy Consolidation	884.12	631.81	511.73	472.39
Paddy Drainage	151.51	107.43	86.62	79.87
Upland Consolidation	389.16	275.94	222.48	205.16
Upland Irrigation	652.66	466.39	377.74	348.70

Table 8.15. Total Accumulated Desired Investment for Projects, by Different Ratios of Actual to Desired Investment by 1985 (1,000,000 Won).

Project	Ratio of Actual to Desired Investment			
	0.6	0.8	1.0	1.2
Tideland Development	20,463	15,373	12,671	11,754
Upland Development	51,861	37,494	30,372	28,065
Large-Scale Irrigation	79,872	62,862	52,292	48,561
Small-Scale Irrigation	92,555	67,674	55,254	51,139
Paddy Consolidation	67,158	47,888	38,746	35,757
Paddy Drainage	17,241	12,204	9,833	9,066
Upland Consolidation	30,992	21,938	17,675	16,296
Upland Irrigation	59,515	42,437	34,336	31,686

Table 8.16. Total Accumulated Actual Investment for Projects, by Different Actual to Desired Investment, by 1985 (1,000,000 Won).

Project	Ratio of Actual to Desired Investment			
	0.6	0.8	1.0	1.2
Tideland Development	12,278	12,298	12,671	14,104
Upland Development	31,117	29,995	30,372	33,677
Large-Scale Irrigation	47,923	50,289	52,292	58,273
Small-Scale Irrigation	55,533	54,139	55,254	61,366
Paddy Consolidation	40,295	38,310	38,746	42,908
Paddy Drainage	10,345	9,763	9,833	10,879
Upland Consolidation	18,595	17,550	17,675	19,555
Upland Irrigation	35,709	33,950	34,336	38,024

Table 8.17. Total National Project Investment by Different Ratios of Actual to Desired Investment, by 1985 (1,000,000 Won).

Investment	Ratio of Actual to Desired Investment			
	0.6	0.8	1.0	1.2
Intended	243,861	243,861	243,861	243,861
Desired	419,659	307,870	251,180	243,322
Actual	251,795	246,296	251,180	278,786

Table 8.13 presents total accumulated land areas under implementation process (storage), that is, land which a project is initiated but not completed. By and large, the same sort of nature as we observed in Table 8.12 can be also observed in this table. As expected, as the ratio of actual to desired investment decreases, the area under implementation process increases. This directly results in an increase in the desired investment to complete projects under implementation. This is reflected in Table 8.14, where total accumulated desired investment is shown.

An interesting fact is found in Table 8.15, where total accumulated actual investment is shown. In a case where the expected average delay time to complete the project is rather short, the actual investment decreases until the ratio reaches 0.8, then increases.[2] In a case where the expected delay time is comparatively long (tideland development and large-scale irrigation projects, 2.5 years, respectively),

[2]This may be caused by the fact that DT, which is 0.25 for this subroutine, is still large relative to delay, DEL, for these projects.

as the ratio increases, the actual investment tends to increase. However, the overall picture in aggregate shows that the actual investment decreases until the ratio reaches 0.8, then starts to increase, as shown in Table 8.16. The aggregate total desired investment decreases continuously as the ratio increases. Remember, we kept intended investment constant over time regardless of the alternative policies on actual budget allocation.

The analysis, thus far, did not give us precise information on economic efficiency. The precise measurement of economic gains or losses may need some sort of benefit-cost analysis framework. The same thing can be examined by comparing a performance variable such as total value added in the agricultural sector by alternative policies on the actual investment relative to the desired investment. However, here we adopt a simple scheme. That is average actual unit costs of improved land, which is measured by dividing the total actual investment (Table 8.15) by total land improved (Table 8.12). This is shown in Table 8.17. As expected, as the ratio increases, the unit cost decreases, without exception, until the ratio reaches 1.0, then starts to increase. The percentage change seems to be related to the nature of unit cost functions given in Figure 4.1 for individual projects. Generally speaking, the actual unit costs are 10 to 17, 0.5 to 2, and 10 to 11 percent higher, respectively, when the actual investment is made by 60, 80 and 120 percent of the desired one, compared to that when the actual investment is equal to the desired one.

In summary, the main subject of this chapter has been sensitivity tests on model parameters. In section two, we hesitated to indicate

Table 8.18. Average Actual Unit Costs (1,000 Won/ha) of Improved Land and Relative Efficiency, by Different Ratios of Actual to Desired Investments, by 1985, Computed From Tables 8.12 and 8.15.

Project	Ratio of Actual to Desired Investment			
	0.6	0.8	1.0	1.2
	Actual Unit Costs			
Tideland Development	717	625	611	671
Upland Development	163	146	144	158
Large-Scale Irrigation	591	518	513	567
Small-Scale Irrigation	436	390	388	428
Paddy Consolidation	132	119	118	130
Paddy Drainage	128	117	116	128
Upland Consolidation	90	82	81	90
Upland Irrigation	158	143	141	156
	Relative Efficiency			
Tideland Development	1.173	1.023	1.000	1.098
Upland Development	1.132	1.014	1.000	1.097
Large-Scale Irrigation	1.152	1.010	1.000	1.105
Small-Scale Irrigation	1.124	1.005	1.000	1.103
Paddy Consolidation	1.119	1.008	1.000	1.102
Paddy Drainage	1.103	1.009	1.000	1.103
Upland Consolidation	1.111	1.012	1.000	1.111
Upland Irrigation	1.121	1.014	1.000	1.106

which parameters were sensitive and which were not. There were three major reasons for this: (1) the data base for the model presented here is poor, (2) variables or parameters are interrelated with each other, and (3) we did not examine all relevant response variables, some of which may have opposite effects. What needs to be done in the future is self-evident from the above discussion. What is less evident is that: (1) as indicated earlier in this chapter, some sort of factorial experimental design seems desirable to explore interdependence of parameters or variables, (2) as indicated in each of the mathematical model chapters, some parts of model structure need further study. In short, data improvement, refinement of model structure and more intensive sensitivity tests must be continued.

CHAPTER IX

POLICY EXPERIMENTS AND THEIR RESULTS

In this chapter, we present the basic results of the model projections. Since the model is being built for agricultural sector planning purposes, we must first identify the policy or instrumental variables that have an effect in changing farmers' decision variables and at the same time can be controlled directly or indirectly by the public decision-maker. The main task of a plan is to identify which policy or instrumental variables contribute most to attaining development goals and then set up government action on the levels of these policy variables so as to attain a maximum possible amount of the desired outcomes while avoiding undesired outcomes from available resources.

Since we have already identified these policy variables and performance variables in Part I, in this chapter we will first discuss an experimental design for policy runs. Table 9.1 contains the policy variables under consideration and their possible values or levels. As there are a large number of choices in the levels of a policy variable, one cannot examine all possible values. Therefore, one is forced to pick from the range of policy variable levels, and this may involve arbitrariness.

We already have a set of the policy variable levels in the computer program for the initial run. It is convenient for the policy level for each policy variable to be stated in terms of these initial

Table 9.1. Levels of Policy Variables.

Policy Variable	Relative to Initial Run[1]			
	Lower	Medium	Higher	Likely
1. Land and Water Development Investment	0.60	0.80	1.00	0.80
2. Biological Research Outcome	0.60	0.80	1.00	0.80
3. Extension Budget	0.75	1.00	1.50	1.50
4. Product Price	0.80	0.90	1.00	0.90
5. Factor Price[2]	1.50	1.00	0.80	1.50
6. Government Credit Supply	0.50	1.00	1.50	1.00
7. Government Interest Rate	1.50	1.00	0.50	1.00

[1] Initial run refers to all conditions appearing in the computer program in Appendix A, except notated in this chapter.

[2] Figures are for fertilizer and pesticides, and figures for other materials are 1.2, 1.0, 0.9 and 1.2, respectively.

levels. We have specified four sets of policy levels in Table 9.1: lower, medium, higher and likely. In the initial policy levels appearing in the computer program, more or less optimistic levels are assigned for some variables. For example, land and water development investment has an initial value that may be considered the maximum level the government can afford to invest. The result of the biological research is also based on an optimistic view. The same thing is true for product prices, specifically grain prices, which are at the levels corresponding to the KASS policy alternative II and are higher than implicitly stated in the third five-year plan. For these variables, the initial levels stated in the computer program are supposed to belong to the "higher" policy level.

A "higher" policy level does not necessarily imply a high value; instead, this should be interpreted as favorable to the agricultural sector. For example, lower factor prices and government interest rates appear in the "higher" policy level column.

To make the policy runs simple and to capture clearly the effect of change in policy level, we have changed several behavioral equations. The equations changed for this purpose are as follows:

1. National extension budget equation

$$GBEX(t) = GBEXI$$

where GBEXI is the initial year's extension budget.

2. Factor price equation

$$PX_{i\ell}(t) = PXP_{i\ell}$$

where $PXP_{i\ell}$ is again the initial year's factor price level.

3. Government credit supply equation

$$GL_i(t) = GLI_i$$

where GLI_i is again the initial year's credit supply

4. Government interest rate

$$GLIR_i(t) = GLIRB_i$$

where $GLIRB_i$ is again the initial year's rate.

Thus far we are concerned with the levels of individual policy variables. That is, for each policy variable, three runs are made for the lower, medium and higher levels. On the other hand, it is theoretically possible to make the factorial design for the experiment with seven factors and three levels for each factor. However, we adapt here a simple design, partially because the model is not ready for real world application, as stated earlier, and partially because of time and budget constraints. That is, four additional runs are made: (1) the first run, where all policy variables have the "lower" level, as specified in Table 9.1, (2) the second run, the "medium" level, (3) the third run the "higher" level, and (4) the fourth run the "likely" level.

For simplicity, any departure from the medium level in each policy run is assumed to take place from 1975, except research outcomes that vary from the beginning. At any rate, more realistic experimental designs and runs require data improvement and, second, interaction with a group of public decision-makers in order to find out their interests and the policy levels they think they can afford.

There are many response variables for the interested policy-maker or researcher to look at. However, we will examine the policy response in terms of the national average rice yield for runs for individual policy variables. We will occasionally also present other relevant response variables, too. Rice is the most important crop in Korea in terms of production as well as consumption, and the major objective of this study is to project the yield level of major commodities. However, there are some policy variables that affect other performance variables.

Let us start with the land and water development policy. A partial result is shown in Table 9.2. It seems that this policy variable does not affect rice yield very much. This does not necessarily lead to the conclusion that land and water development projects are not very effective means to achieve development or growth.

Table 9.2. Model Response to Change in Land and Water Development Investment in 1985.[1]

Response Variable	Unit	Land and Water Development Investment Relative to Basic Run		
		0.6	0.8	1.0
Average Rice Yield	Ton/Ha	5.857	5.879	5.900
Total Rice Production	1,000 Ton	7,377	7,405	7,431
Total Labor Demand	Million Hrs.	1,211	1,168	1,131

[1]In this chapter, any kind of national total or average figure is computed based on land area allocated to each crop projected by the KASS initial version under policy alternative II.

The major purposes of undertaking these projects are to: (1) increase production rate, (2) save labor and (3) induce to reduce the degree of uncertainty. As seen in Table 9.2, total labor demand decreases as the levels of these projects go up. However, this is not a sufficient indication of reduction in labor demand. As stated in Part II, we did not project the average labor demand, but we intended to project labor demand for the nonmechanized process of production which is defined in the resource allocation component model as the traditional production process. A prerequisite of mechanization for field machines is known to be land consolidation. Since we did not include the mechanization process in this subcomponent model, land and water projects cannot be fully evaluated.

A more important omission in this model has to do with the uncertainty problem stemming from weather. In a normal year, there is not much difference in yield levels among different types of irrigation systems. However, the irrigation system is designed to prevent production curtailment in a bad weather year. Our model, unfortunately, does not permit us to estimate how much uncertainty is reduced by the water development projects.

Let us now examine how the average rice yield would be increased by biological research results. Biological research is a crucial variable affecting yield level and, hence, production, as seen in Table 9.3. Thus, one can conclude that food self-sufficiency in any food-deficit country will depend heavily on its ability to achieve an efficient research institute that can advance technology. Figure 9.1 compares the average rice yield levels corresponding to the policy level specified in Table 9.1 with the yield level projected by the KASS under policy alternative II. It can easily be seen that the present projection, regardless of policy level, is higher than that made in the initial version of the KASS under policy alternative II. There are several reasons for this overestimation. First, as seen from the figure, the initial condition or level for the present model is higher than that in the KASS used. Second, KASS assumed about a 30-percent increase in rice yield at the experiment station in the early 1970s. These seem to be the major factors contributing to the higher estimations.

In Table 9.4, we present the rice yield response to a change in the extension budget. It seems that the structural elasticity is

Table 9.3. Model Response to Change in Biological Research Outcome in 1985.

Response Variable	Unit	Research Outcome Relative to Planned One		
		0.6	0.8	1.0
Average Rice Yield	Ton/Ha	5.485	5.879	6.273
Total Rice Production	1000 Ton	6,908	7,405	7,900

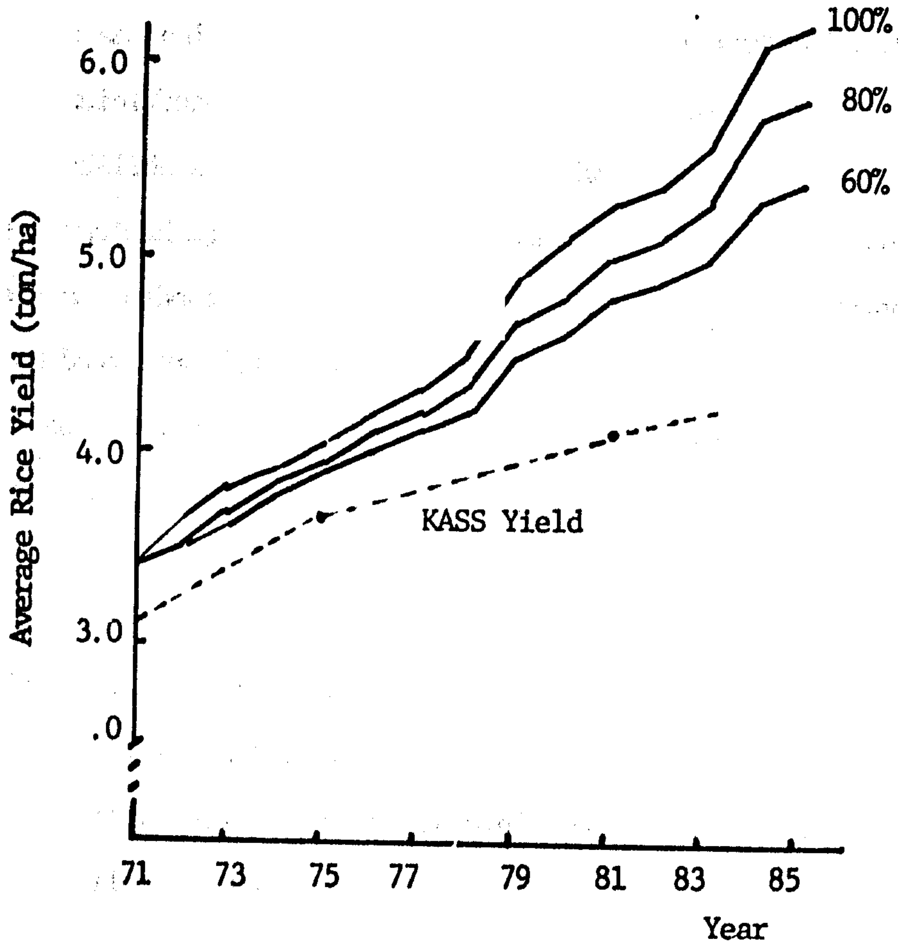

Figure 9.1. Average national rice yield level projected under three policy levels on research outcomes, specified in Table 9.1 and that projected by KASS under policy alternative II.

relatively low, however, extension is certainly one of the effective measurements of attaining development goals.

Table 9.4. Model Response to Change in Extension Budget in 1985.

Response Variable	Unit	Extension Budget Change Relative to Basic Run		
		0.75	1.00	1.50
Average Rice Yield	Ton/ha	5.798	5.879	5.993
Total Rice Production	1000 Ton	7,301	7,405	7,547

Table 9.5 shows the national average yield response to the product price level. The price elasticity turns out to be small. In fact, product price levels alone may not be a very effective means to affect the physical production level. That is, price policy should be interpreted as a complementary factor with technological change and also determined from the viewpoint of the terms of trade or welfare consideration for the farm sector. As seen in Table 9.5, total value added changes proportionally with the price level change.

Table 9.5. Model Response to Change in Product Price in 1985.

Response Variable	Unit	Product Price Change Relative to KASS Alternative II Price Set		
		0.8	0.9	1.0
Average Rice Yield	Ton/ha	5.858	5.879	5.907
Total Rice Production	1000 Ton	7,379	7,405	7,439
Total Value Added	Billion Won	2,308	2,660	3,001

How about response to changes in factor prices? As shown in Table 9.6, and as expected, production and, hence, total value added decreases and total cost increases as the factor price level increases. Again, the structural elasticity seems very low and policy for factor price should be aslo determined by considering not only production, but also welfare of the rural sector, more specifically income redistribution, together with product price policy.

Table 9.6. Model Response to Change in Factor Prices in 1985.

Response Variable	Unit	Factor Price Change[1] Relative to 1970 Level		
		Low	Unchanged	High
Average Rice Yield	Ton/ha	5.881	5.879	5.844
Total Rice Production	1000 Ton	7,407	7,405	7,360
Total Material Costs	Billion Won	304	320	322

[1]For "high" factor price, prices of fertilizer, pesticides and other materials are 1.5, 1.5 and 1.2, respectively, as compared to those in 1970, and for "low" factor price, those are, 0.8, 0.8 and 0.9, respectively.

The standard textbook on micro economics teaches us that production response is zero with respect to proportional changes in product and factor prices. That is, when both prices change by the same proportion, there would be no change in factor use and, hence, in production. On the other hand, according to Tables 9.6 and 9.6, the supply elasticity with respect to product price change seems higher than that with respect to factor price change.

There are some reasons for the difference. Production is certainly geared to producer incentive. This incentive can be measured by economic returns to producer's owned fixed resources, land and labor. When the share of the rest of production factors is relatively small, the level of producer's incentive, value added or profit is much more sensitive to product price change than to a change in factor prices. Therefore, it does not matter whether the product price is increased by, say, 10 percent or prices of factors supplied by the nonfarm sector are decreased by 10 percent. The level of producer's incentive is considered in adjusting factor demand elasticities (see Equations 7.40 to 7.42). That is, the profit level, among others, is supposed to shift the elasticity function in Figure 7.2. This profit level is also assumed to accelerate the adoption of new technology (see Equation 5.5). At the same time, farmer-owned capital is defined here to be proportional to the gross revenue. Hence, changes in product price will affect factor use more than changes in factor prices. A lower elasticity of rice yield with respect to factor price change stems from other model assumptions, too. The most important reason is that a lower value of demand elasticity for factor is assigned since it is found to be extremely low [see Lee (L.4)]. Second the productivity coefficient of the so-called conventional input is positively related to changes in factor price (see Equation 6.11). This means that when factor price increases: (1) demand for this production factor will decrease, but (2) production elasticity tends to increase since factor demand elasticities with respect to factor prices are far lees than unit. Thus, the effect of factor price changes on production response will somewhat cancel out each other.

Tables 9.7 and 9.8 present model response to government credit policy, first for the amount of credit supply and second for interest rate.

Table 9.7. Model Response to Change in Government Credit Supply in 1985.

Response Variable	Unit	Government Credit Supply Relative to Basic Run		
		0.5	1.0	1.5
Average Rice Yield	Ton/Ha	5.879	5.879	5.880
Total Rice Production	1000 Ton	7,405	7,405	7,405
Total Capital Cost	Billion Won	56	54	54

Table 9.8. Model Response to Change in Government Interest Rate in 1985.

Response Variable	Unit	Government Interest Rate Relative to Initial Level		
		0.5	1.0	1.5
Average Rice Yield	Ton/Ha	5.894	5.879	5.861
Total Rice Production	1000 Ton	7,424	7,405	7,381
Total Capital Costs	Billion Won	42	54	60

The government loan rate does not affect physical production. This seems to stem from enough credit being available from the noninstitutional private money market. But the farmer is asked to pay a higher interest rate and this fact is reflected in total capital costs in Table 9.7. On the other hand, a change in government interest rate affects physical production slightly and total capital costs greatly. Thus, both policy variables also influence income distribution.

Thus far, we have assumed that only one policy variable is variable, other policy variables being kept at the medium level, as specified in Table 9.1. Let us now examine what happens when all policy variables change in directions favorable or unfavorable to the farm sector. That is, all the policy variables are assumed to change from medium levels to lower or higher level at the same time.

Let us look at what happens to total grain production. Grain as defined here includes rice, barley, wheat, other grains, pulses and potatoes (whose yield level is already specified in terms of grain equivalent). The result is shown in Figure 9.2. For comparison, total grain production projected by the initial version of the KASS under policy alternative II is also presented, denoted by * in 1971, 1975, 1980 and 1985. Again as seen in the figure, the present projection, regardless of the policy level, is higher than the KASS projections, especially after 1975. The possible reason for this was already discussed. Total consumption needs (to be taken into account of the market losses or production deflators) are also shown in Figure 9.2. In order to achieve food self-sufficiency earlier, more development effort has to take place earlier, since with the higher policy level, it is only possible to achieve the food self-sufficiency after 1979; with the medium level, after 1981; and with the lower level it is not possible even by 1985. We will come back to this problem later.

Going back to Figure 9.2, note what happens after 1975. Remembering that all policy levels except the biological research outcomes change. Total grain production is more or less depressed for 2 or 3 years right after 1975 with the lower policy levels. Total grain production is accelerated from 1975 with the higher policy levels. In any case, grain production is growing smoothly. This is so because we assumed that all policy levels were constant over time, that the

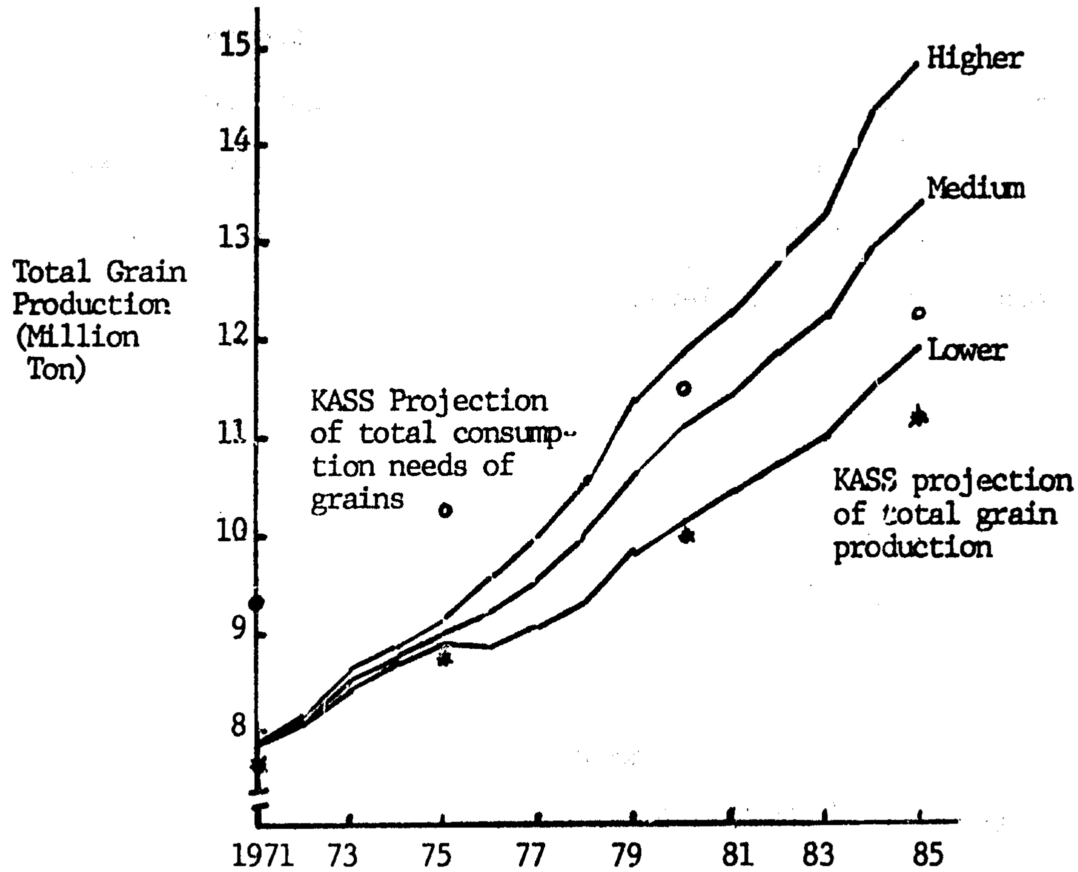

Figure 9.2. Total grain production projection based on three different policy levels, specified in Table 9.1, projected by KASS under policy alternative I denoted by * and consumption needs denoted by o in 1971, 1975, 1980 and 1985.

biological research outcomes materialzied continuously, and we did not consider a main factor causing production to fluctuate over time (weather).

Let us find out what happens to other response output variables due to a change in the level of all policy variables. Partial results are shown in Table 9.9. Notice that all output variables specified are responding well to the policy input levels. As noticed earlier, total rice production here is high as compared to the KASS projection which is 5,451 for 1985. The KASS projection of total material costs is 141, which is lower than that under any policy level considered here. Total value added projected by the KASS is 1,166, which is higher than that under the lower policy level, but less than that for the other levels. However, it is worthwhile to note that the KASS total value added includes all agricultural commodities. Thus, we should say that all projections made here are considerably higher than those made by the KASS under policy alternative II. This fact stems directly from the higher yield levels of major crops, which, in turn originate largely from superior biological research outcomes. Material costs also turn out higher in order to support higher production levels. The labor demand projection by the KASS is available, but we hesitate to compare these results since we did not consider mechanization in this model.

Table 9.9. Model Response to Change in the Level of All Policy Variables in 1985.

Response Variables	Unit	Policy Level			
		Lower	Medium	Higher	Likely
Total Rice Production	Million Ton	6,564	7,336	8,119	7,389
Total Material Costs	Billion Won	174	187	207	231
Total Capital Costs	Billion Won	41	26	13	37
Total Value Added	Billion Won	1,019	1,361	1,716	1,296
Total Labor Demand	Million Hrs	5,356	5,085	4,812	5,113

Lastly, we want to present the national average yield for individual crops, projected on the likely policy level set. These results appear in Figures 9.3 through 9.6. As compared to those projected by the KASS under policy alternative II, yield levels of rice, wheat, fruits, vegetables and potatoes projected by this study are higher, those of barley and tobacco are approximately the same, and those of other grains, pulses and industrial crops, which are minor crops, are lower.

As indicated earlier, the sources of the difference seem to stem largely from: (1) difference in initial yield levels, (2) assumed biological research outcomes, and (3) some other model assumptions, such as change in age cohort of perennial crops, past input use effect on yield level for perennial crops, etc.

At any rate, compare the growth rates of yield with perceived accumulated rate of increase in yields due to the biological research in Table 5.1. There is a close correspondence between them. Thus, we can conclude that the biological research is the crucial factor affecting physical productivity while other policy variables are complementary with research outcomes or measures for attaining other development goals, such as income level, income redistribution, reduction in uncertainty, labor requirement, costs, etc. This conclusion does not imply that the other policy measures are unimportant. What we mean is that biological research and diffusion of results are jointly more important in achieving physical productivity growth.

In summary, the results of policy experiments in this chapter are consequences of assumptions (many of which are based on poor data) of the model presented in this study. In almost all chapters, we have

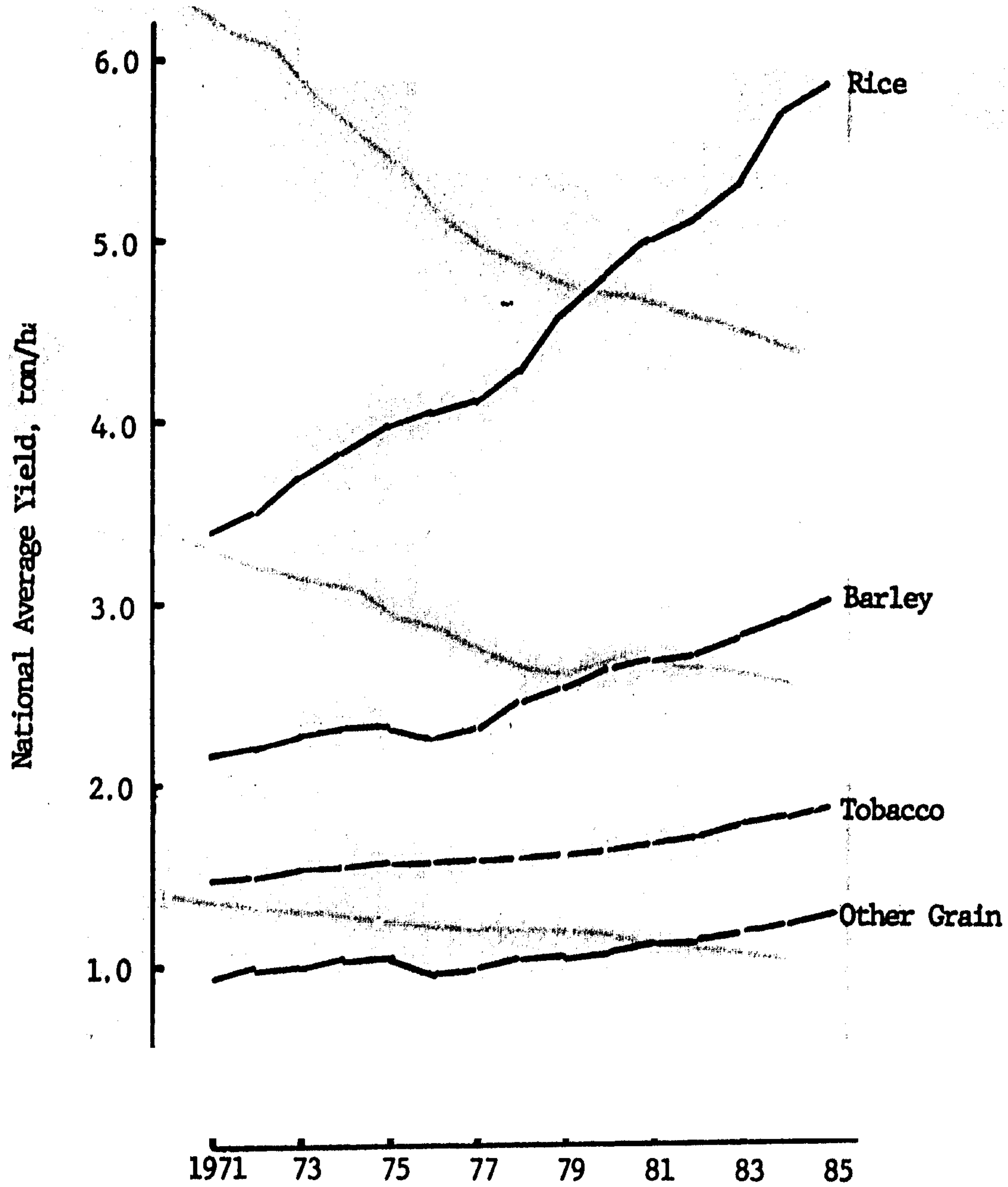

Figure 9.3. Projection of yields of rice, barley, tobacco and other grains, based on the likely policy level set.

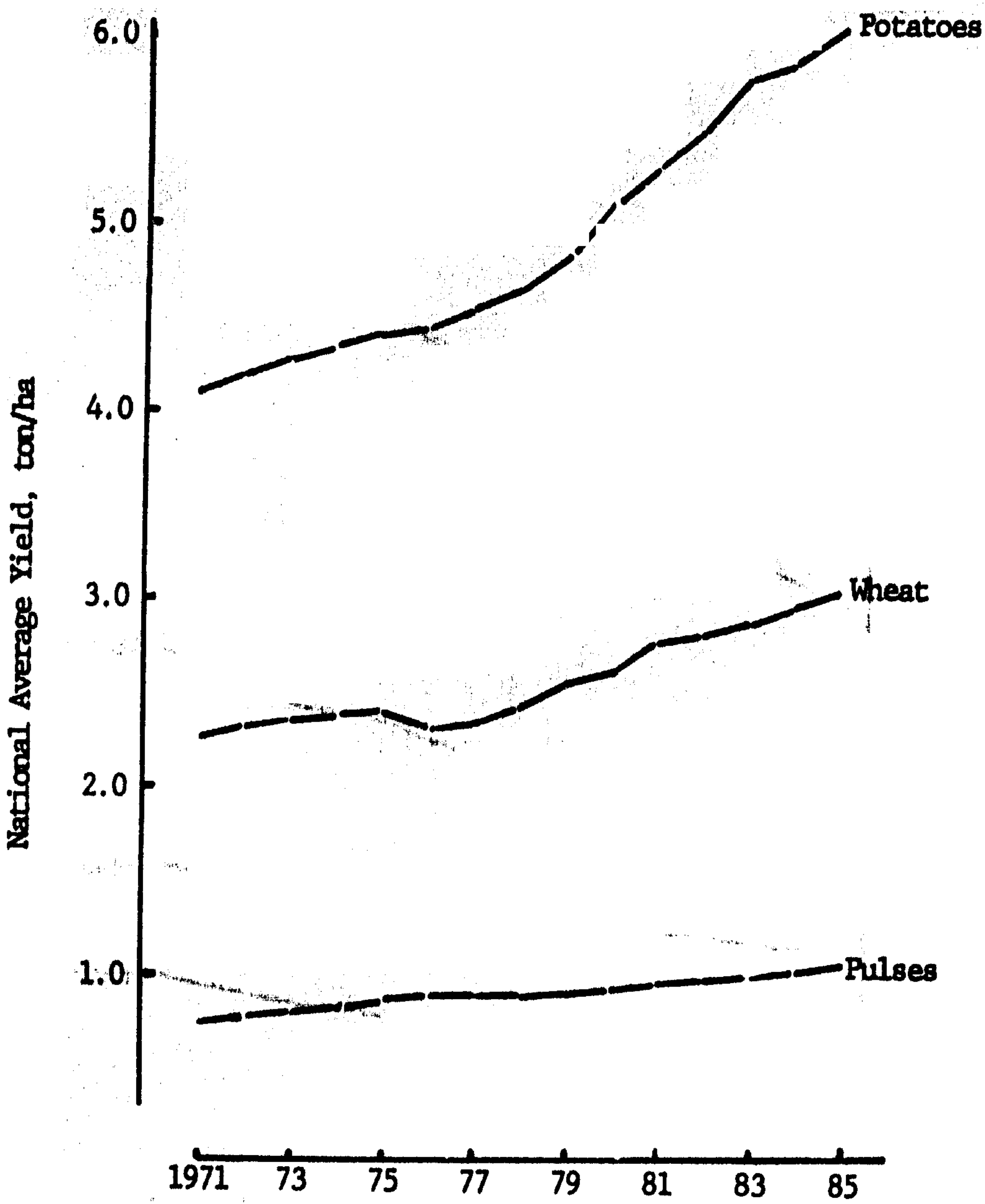

Figure 9.4. Projection of yields of wheat, pulses and potatoes, based on the likely policy level set.

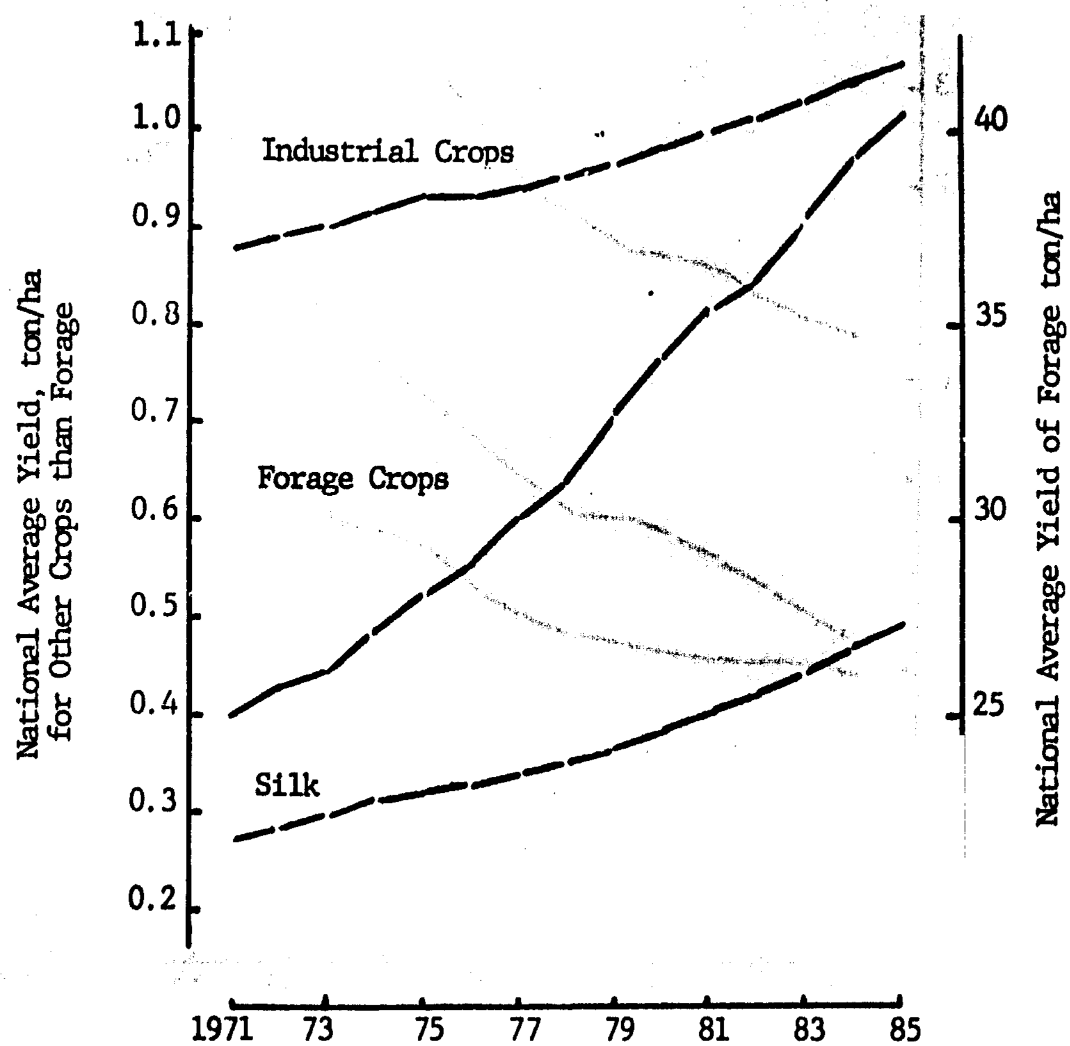

Figure 9.5. Projection of yields of silk, industrial crops and forage crops, based on the likely policy level set (scale in right-hand side for forage, and that on left for others).

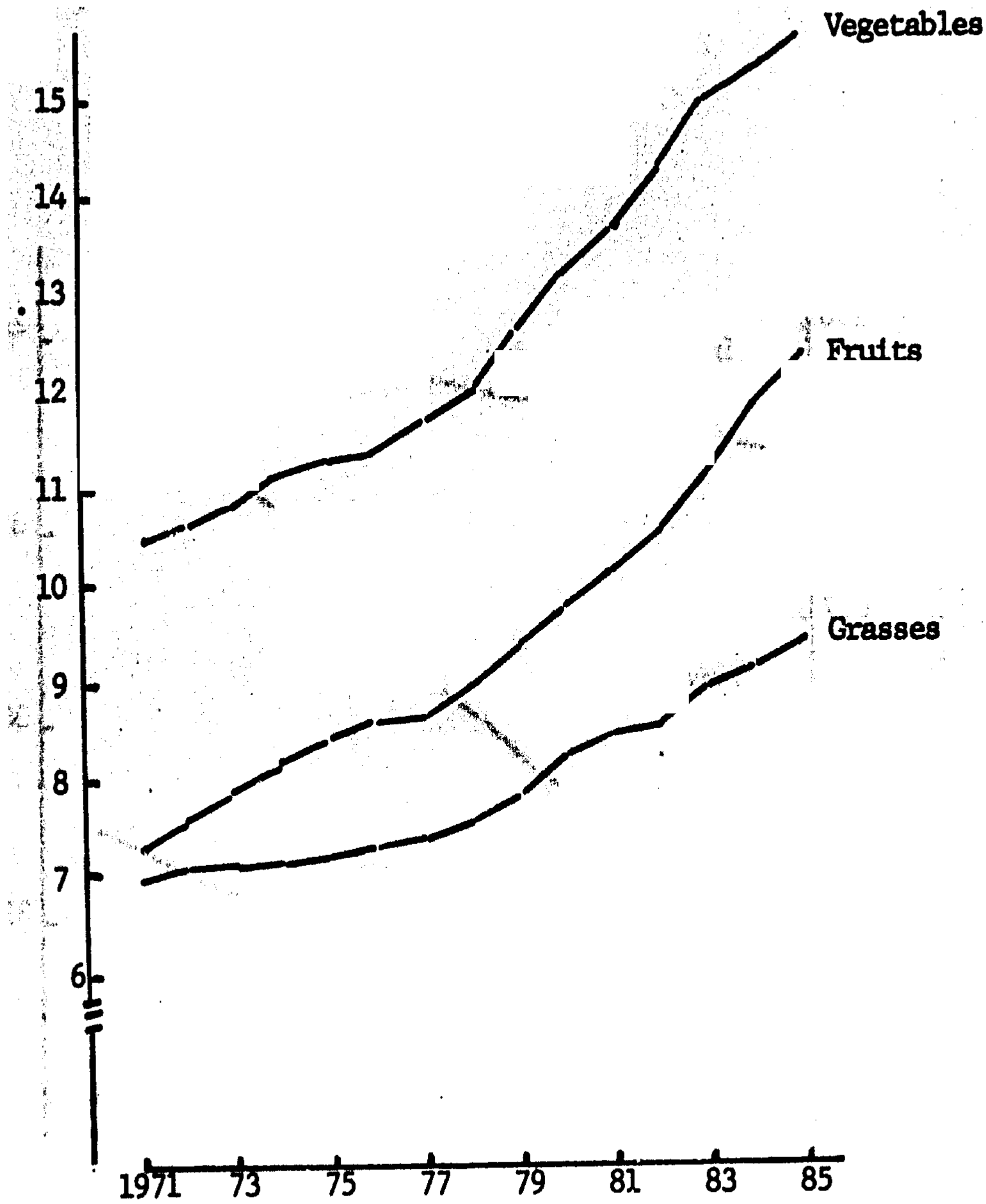

Figure 9.6. Projection of yields of vegetables, fruits and grasses, based on the likely policy level set.

discussed weakness of the present study, especially, in terms of data. This author does not intend to project the future values of the relevant variables accurately in this study but, instead, to make a model that can be used to project these variables when better data become available. Thus, the results presented here should be interpreted as tentative. The purpose of the computer experiments in this chapter is to aid further model refinement. The possible areas to be refined conceptually have been discussed in each mathematical model chapter, and the need for better data has been discussed repeatedly at various appropriate points.

PART IV

POLICY IMPLICATIONS AND CONCLUSIONS

CHAPTER X

POLICY IMPLICATIONS AND CONCLUSIONS

After constructing a mathematical model in Part II, based on the theory presented in Part I, we tested the model in Chapter VIII to determine whether it works properly. We also tested the model to determine whether it responded properly to changes in policy inputs, and whether it can help identify a set of policy variables and their levels that can contribute to attaining the development goals in Chapter IX. It is in order that we draw policy implications and evaluate the model.

Part IV contains two concluding chapters. In the first chapter, we seek policy implications and conclusions based on the simulated results of the model. At the same time, we want to discuss again the weaknesses of our model and further study needs to make the model more realistic for policy making. Finally, Chapter XI summarizes the overall study, including conclusions.

What kinds of conclusions can we draw from the simulated results of the model in terms of policy recommendations? In discussing these policy implications, we must keep several points in mind. First, the object of the study was to project yields for specific crops under consideration as a result of public policies, projects and programs designed to directly or indirectly affect the production level. A change in the yield of a crop or a group of crops is likely to affect the pattern of resource allocation. Changes in yields and land allocation will certainly induce change in the producer price level and structure. This, in turn, induces change in the yield level and allocation of land, labor and other production factors. This repercussion takes place unless the demand elasticities for different commodities are identical and the yield level and factor demand change proportionately among crops. However, these conditions can hardly hold. In other words, we are not able to fully evaluate the policy alternatives from the model presented here unless it is linked with the resource allocation and commodities demand component of the overall KASS model.

Second, the policy input signals in this model are kept as simple as possible. Thus, the model provides limited information. In order for the model to supply more useful information for policy making, interaction with public decision makers is needed to determine (their) interest and the general direction of policy variables, programs and projects.

Third, a simple mechanism has been adapted for certain behavioral relationships Take the farmers' own capital for investment for example. As indicated earlier, farmers' consumption, saving and investment decisions are more or less jointly determined. The mechanism for this joint determination is not clearly known. Since our simple mechanism does not fully reflect this complicated process, errors in making projections can be expected.

Fourth, several important variables that may affect production rates are omitted. Transportation, electrification, etc., are examples, In addition, in the process of economic transformation, farm size is likely to increase, which will likely affect productivity. These relationships are not included in the present model.

Lastly, the data base for themodel is poor. That is, inadequate checks have been made on how well the data used here represent the real world situation in many instances. This may cause a strong bias in drawing policy implications.

With these reservations, let us now return to our main subject. We will discuss policy implications exclusively in terms of production, partly because the present model is designed for the production system, and partly because other development goals can be better evaluated when the model is merged with other model components.

To evaluate policy alternatives, we must first identify those policy variables that will affect the system. We have specified one set of conventional production factors, and, at the same time, another set of structural change variables in our production function for each crop in each region. How much is each of these variables conceived to be contributing to the growth of productivity? We have three different conventional inputs and ten structural change variables for each of 13 crops in each of three regions. Thus, it becomes too complex to discuss all these variables for all crops at the same time in order to draw policy implications. Therefore, we select two crops in Region 1, for illustrative purposes--an annual crop, rice, and a perennial crop, tree fruit. Structural variables are grouped appropriately, as shown in the following tables.

Table 10.1 shows the sources of rice yield productivity growth

Table 10.1. Sources of Yield Productivity Growth Rate (in Percent) for Rice in Region 1. Based on Medium Policy Level Set Specified in Table 9.1.

Year	Conventional Input Use Change	Research and Extension	Water and Land Development	New Land Development	Total
1971	0.11	1.18	1.18	-0.03	2.44
1972	0.34	2.30	0.84	-0.01	3.47
1973	0.75	5.69	0.56	-0.06	6.94
1974	0.37	2.12	0.46	-0.02	2.93
1975	0.35	1.78	0.42	-0.03	2.52
1976	0.45	2.87	0.40	-0.25	3.47
1977	0.26	2.12	0.38	-0.22	2.54
1978	0.33	3.01	0.37	-0.15	3.56
1979	0.79	7.54	0.36	-0.08	8.61
1980	0.27	2.43	0.35	-0.03	3.02
1981	0.31	2.75	0.34	-0.00	3.40
1982	0.23	1.94	0.33	0.01	2.51
1983	0.32	2.73	0.32	0.01	3.38
1984	0.80	6.68	0.32	0.02	7.82
1985	0.24	1.89	0.32	0.02	2.49
Total	5.92	47.03	6.95	-0.082	58.98
Average	0.39	3.14	0.46	-0.05	3.93

from 1971 to 1985. This projection is based on what we call the medium policy level set, defined in Table 9.1. For the 15-year period, rice productivity increases by 6 percent due to increased use of conventional inputs, 47 percent due to research and extension, 7 percent due largely to water development, and decreases by 0.8 percent due to bringing marginal land into production for a net total of about a 60 percent increase. The simple average annual growth rate is 0.4, 3, 0.5 and -0.0005 percent, respectively, in the order of the factors listed above, and the annual total average growth is about 4 percent.

As seen in Table 9.1, the medium policy level set assumes the factor price level remains unchanged at the 1970 level. Thus, the sources of conventional input use change are other than changes in factor prices. As shown in Table 10.2, in the case of fertilizer for rice in Region 1, the sources of factor use change are product price change by 0.45 percent, research and extension by 7 percent, and land and water development by 0.3 percent annually. Average annual total growth rate is about 8 percent, and total fertilizer use increases by 117 percent from 1971 to 1985.

The effect of research and extension and land and water development are computed such that the effect of change in the conventional input use induced by these structural changes are subtracted from the gross effect. On the other hand, the effect of research and extension includes not only research outcomes made available by the public sector, but also innovations by leading farmers.

Table 10.3 presents the same sources of productivity growth for fruits in Region 1. But two additional sources of the growth are considered: past conventional input use and age cohort changes. Total and annual average growth rates for 1971 to 1985 are 62 percent and 4 percent, respectively. The order of importance of the sources is age cohort change, research and extension, current inputs use, past input use, and land and water development. As expected, addition of marginal land causes the average yield to decrease.

Table 10.2. Sources of Growth Rate of Fertilizer Use (in Percent) for Rice in Region 1, Based on Medium Policy Level Set Specified in Table 9.1.

Year	Product Price Change	Own Price Change	Cross Price Change	Budget Change	Research Extensions	Land and Water Development	Total
1971	0.0	0.0	0.0	0.89	2.67	0.50	4.06
1972	0.16	0.0	0.0	0.0	5.18	0.56	5.90
1973	0.63	0.0	0.0	0.0	12.73	0.49	13.85
1974	1.44	0.0	0.0	0.0	4.72	0.41	6.57
1975	1.90	0.0	0.0	0.0	3.93	0.36	6.19
1976	2.03	0.0	0.0	0.0	6.33	0.32	8.68
1977	0.38	0.0	0.0	0.0	4.67	0.30	5.35
1978	0.16	0.0	0.0	0.0	6.62	0.28	7.06
1979	0.07	0.0	0.0	0.0	16.62	0.26	16.95
1980	0.03	0.0	0.0	0.0	5.37	0.24	5.64
1981	0.01	0.0	0.0	0.0	6.11	0.23	6.35
1982	0.01	0.0	0.0	0.0	4.32	0.22	4.55
1983	0.0	0.0	0.0	0.0	6.08	0.21	6.29
1984	0.0	0.0	0.0	0.0	14.93	0.20	15.13
1985	0.0	0.0	0.0	0.0	4.23	0.19	4.42
Total	6.82	0.0	0.0	0.89	104.51	4.77	116.99
Average	0.45	0.0	0.0	0.06	6.97	0.32	7.80

Table 10.3. Sources of Yield Productivity Growth Rate (in Percent) for Fruits in Region 1, Based on Medium Policy Level Set Specified in Table 9.1.

Year	Conventional Input Use Change	Past Input Use Change	Age Cohort Change	Research and Extension	Water and Land Development	New Land Development	Total
1971	-0.20	0.00	0.00	0.48	0.00	-0.09	0.19
1972	0.32	-0.07	1.86	0.73	0.01	0.24	3.09
1973	0.47	0.06	1.86	1.09	0.01	0.11	3.60
1974	0.75	0.20	1.86	1.98	0.01	0.02	4.82
1975	0.48	0.39	1.86	0.62	0.01	-0.12	3.24
1976	0.47	0.42	1.86	0.55	0.01	-0.25	3.06
1977	0.64	0.43	1.86	1.15	0.01	-0.20	3.89
1978	0.89	0.50	1.86	2.11	0.01	-0.07	5.30
1979	1.20	0.62	1.87	3.23	0.01	0.0	6.93
1980	0.61	0.80	1.87	0.68	0.01	0.02	3.99
1981	0.58	0.70	1.87	0.78	0.01	0.02	3.96
1982	0.65	0.64	1.88	1.29	0.01	0.02	4.49
1983	0.80	0.62	1.88	2.15	0.01	0.02	5.48
1984	0.97	0.66	1.89	3.05	0.01	0.02	6.60
1985	0.48	0.70	1.89	0.68	0.01	0.02	3.78
Total	9.11	6.67	26.17	20.57	0.14	-0.24	62.42
Average	0.61	0.44	1.74	1.37	0.01	-0.02	4.16

A change in age composition of tree crop will certainly affect average yield. However, it is doubtful that fruit yields actually increase by 1.7 percent annually for this reason. A possible source of bias is change in age composition over time. We used some rough tentative data because the correct figure will be generated when this model is linked with the other components. The other source of bias is the response elasticity. This is applicable for all structural change variables, however.

What conclusions can be drawn from the analysis of the two cases indicated above? One may easily conclude that the highest-payoff input is technological change made possible by biological research and dissemination of its results. Cochrane [C.5, p. 88-90] observes that two basic factors contributed to an increase in total farm output in the United States: farm technological advance and an increase in the size of the total fixed plant-land. He notes that the former was a minor cause and the latter a major cause during the nineteenth century, whereas the former was the major cause and the latter minor in this century. In another paper, he [C.6, p. 46] claims that "the engine of modern farm production is farm technological advance."

No one would deny validity of this conclusion, even for developing countries, if the productive land frontier has been exhausted. However, we need to understand the mechanism of the engine of the growth. Johnston [J.22] refers to the new technology known as the "Green Revolution" in the Southeast Asian countries as the "seed-fertilizer revolution."

The Korean experience shows that a 30-percent increase in rice yield at the experiment station is associated with about a 100-percent increase in fertilizer application. In other words, the new high-yield varieties are bred so as to be highly fertilizer-responsive. The basic philosophy underlying this direction in crop breeding is to accelerate the supplementation of scare land with fertilizer that can be more easily augmented.

Auer and Heady [A.10] estimate that from 1939 to 1961 the sources of growth of corn production in the U.S. are corn hybridization, 35.5 percent; fertilizer, 31.4; regional specialization, 17.9; and other, 15.2. In other words, the source of productivity growth can be more than seed and fertilizer in the emerging countries. Wharton [W.3] and many others discuss complementary inputs associated with the "Green Revolution."

Barker [B.2], for example, after remarking that "many writers appear to believe that the technological change begins and ends with the introduction of the new rice varieties," insists that "a highly complementary package of inputs is associated with the new rice varieties. This package includes irrigation and water control, fertilizer, methods to control weeds, diseases, and pests. Use of these inputs allows the new varieties to express their yield potential. Without these inputs the grower cannot expect a good yield." He also notes that "the greatest production gains from the new technology have occurred in the best irrigated areas."

Figure 10.1 illustrates how total fertilizer and material costs will increase under the process of economic and technological transformation. Both total factor and fertilizer demands have doubled between 1971 and 1985. Without this package of complementary inputs, it is certain that the new seed technology would not have exhibited its potential.

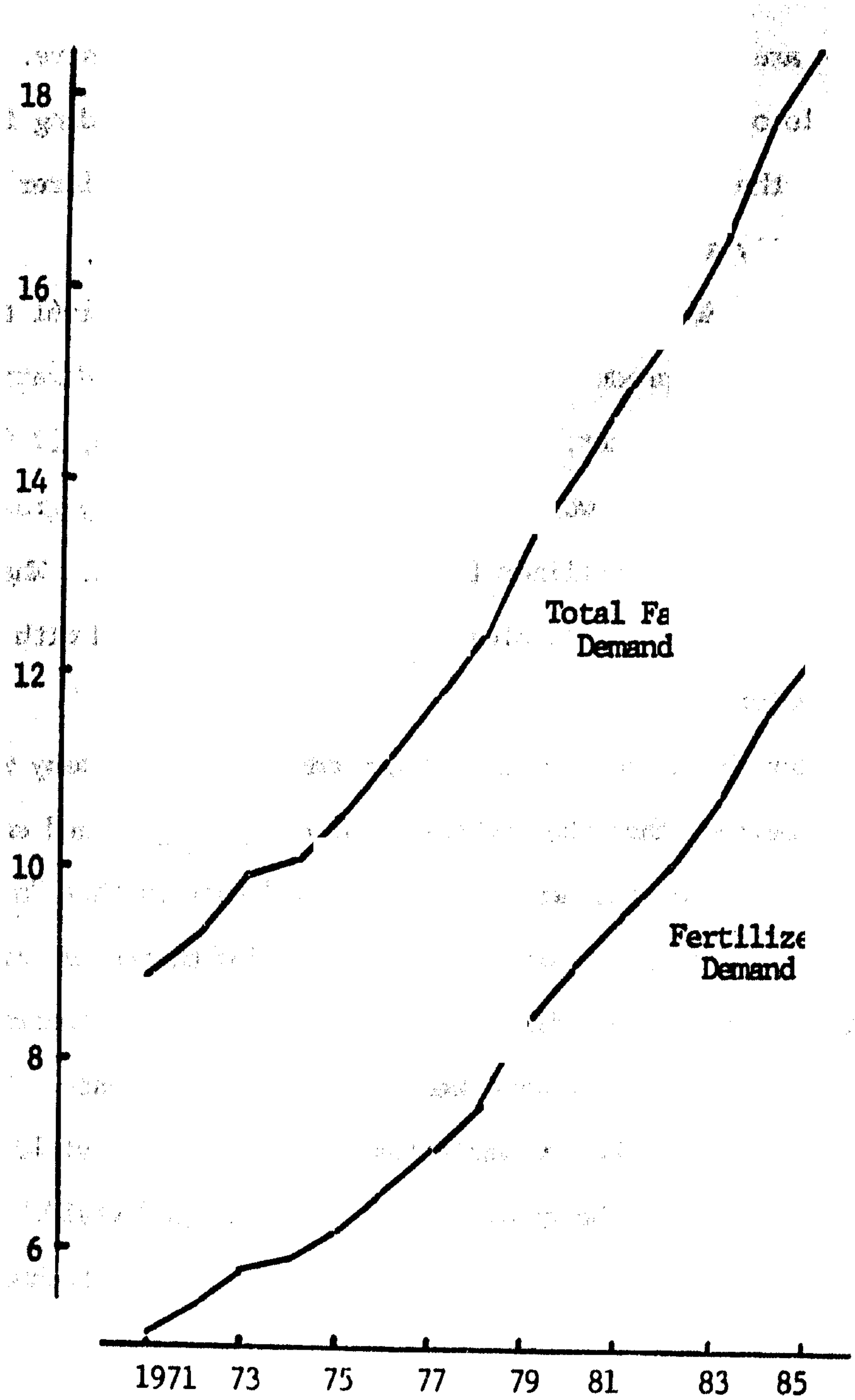

Figure 10.1. Aggregate demand for fertilizer and total factor measured in terms of service and expenditure, based on the medium policy level set specified in Table 9.1.

Krishna [K.10] points out that

> "As a part of development policy, agricultural policy has generally been used negatively--to keep bread and raw materials cheap for a growing industrial sector, and to maximize and transfer to the city for investment the profits of trade in agricultural commodities,"

and adds that

> "If the circumstances of a country permit this critical minimum rate of agricultural growth to be realized while the terms of trade of agriculture are depressed against it in the traditional way, there would be no need for a positive agricultural price policy. But the evidence shows that in many developing countries the minimum rate of agricultural grwoth consistent with rapid and sustained general growth can be quite high; and that a negative price policy cannot be followed without risking failure to achieve or sustain the desired growth."

Krishna also feels that input price subsidization is not a complete substitute for product price guarantees, and that both are needed as complementary instruments of policy for different reasons. He states that

> ". . .product price guarantees are needed in addition to input subsidies because it is not a matter of indifference whether the profitability of a crop is increased by raising the price of the crop or by lowering the prices of inputs,"

and adds that

> "Thus if a support program does accelerate output growth it turns out to be a very profitable investment for the food consumers of a society."

As seen earlier, in the process of economic transformation, a number of economic and technological influences are forcing farms to become more capital-intensive. The resulting demand and the arrangements under which capital is made available to agriculture are determining factors influencing the structure of the farm sector, as Brake [B.15] suggests.

In summary, not only are technological inputs complementary, but factors governing farmers' incentives, including credit and credit costs, are also complementary to varietal improvements. The important question is, however, which is the most critically limiting factor, or which ones can or cannot be supplied easily at reasonable prices in the present Korean agricultural setting. It is not hard to identify this crucial variable from the results of the present study--biological research and dissemination of its results.

Let us momentarily assume that this variable can be easily controlled by public institutions. We have seen that it is impossible for Korea to achieve food self-sufficiency until the 1980s, in light of projections by the KASS and this model. We do not seek an optimal strategy for achieving this goal as early as possible, since that involves a host of economic and technical variables, some of which are outside of the present model. However, we do try to grasp some implications about attaining this goal by manipulating the policy variables in the model.

The first experiment was to determine what would happen if the technological breakthrough takes place much earlier than anticipated (Table 10.4). It is assumed here that biological research results for good grains are forthcoming earlier with the same amount of total accumulated research outcomes over a 15-year period as that in Table 5.1. This would imply a big push in biological research in the mid-1970s. The result of this new experiment run is compared with that based on the medium policy level set in Figure 10.2 in terms of total grain production, where the KASS consumption projection is denoted by *.

Table 10.4. Hypothetical Planned Expected Research Results, in Terms of the Rate of Increase in Experiment Stations Yield, Adjusted by Proportion of Crop that Could Advantageously Use Results (biological Research Results are Assumed to be Forthcoming Earlier with the same Amount Over a 15-Year Period of Total Accumulated Increase in Yield as that in Table 5.1.

Year	Rice	Barley	Wheat	Other Grains	Pulses	Potatoes
1971	0.10	0.05	0.05	0.05	0.05	0.05
1974	0.15				0.15	0.20
1976		0.20	0.20	0.20		
1977	0.15				0.15	0.15
1978		0.05	0.10			
1979	0.05					
1980						0.10
1981				0.10	0.05	
1982	0.05	0.05	0.05			
1983						0.05
Total	0.50	0.35	0.40	0.35	0.40	0.55

The only difference is in the assumptions shown in Table 5.1 versus Table 10.4. Under the new assumption, food self-sufficiency can be achieved in 1978-1979, whereas at the medium policy level set it was possible only after 1981.

How can we achieve an earlier technological breakthrough? Remember the underlying assumption in computing the expected research outcomes at the experiment station by the proportion of crop area that could advantageously use the results. We implicitly assumed

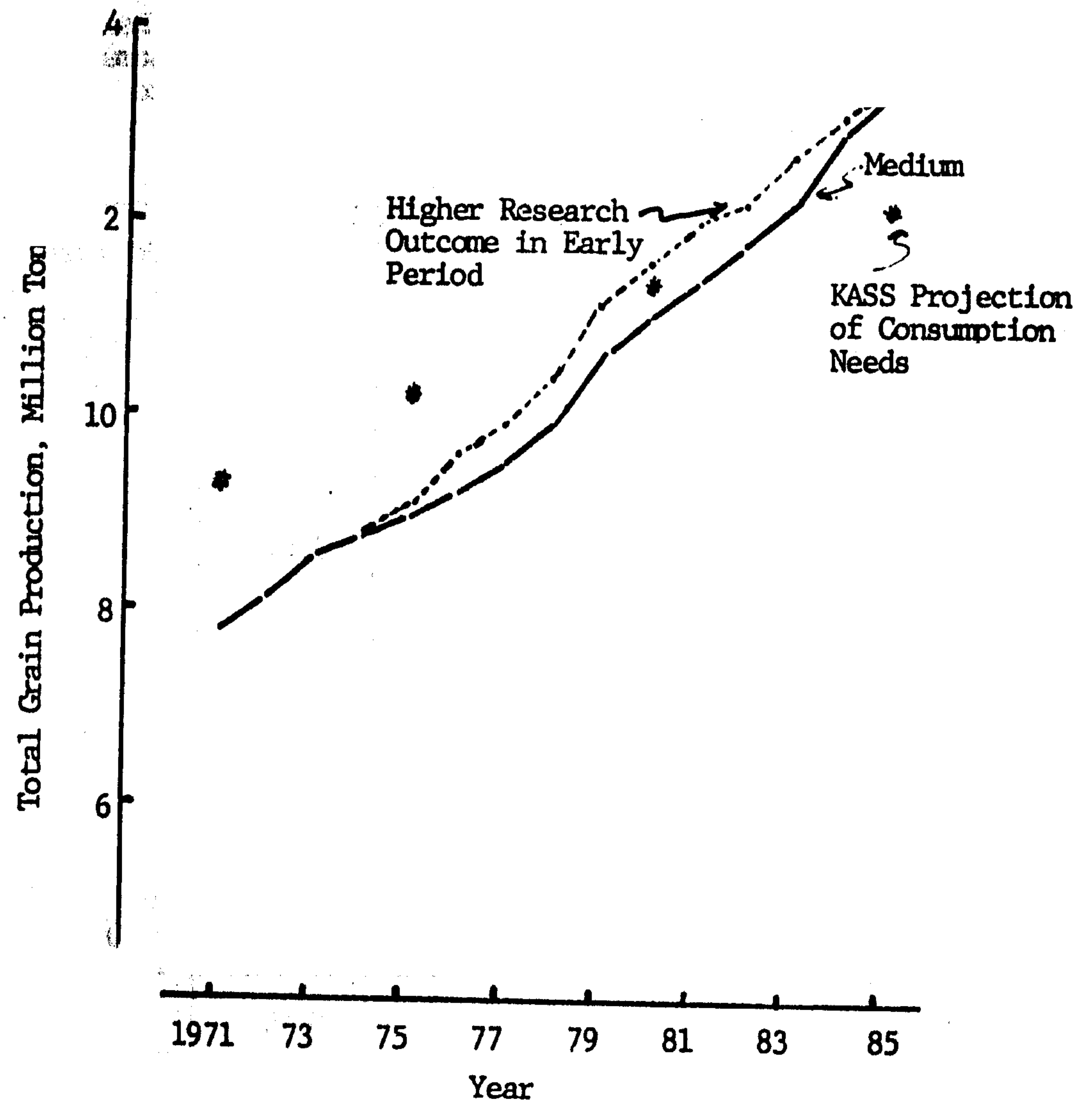

Figure 10.2. Total grain production projection, based on medium policy level set, specified in Table 9.1, and that based on assumption specified in Table 10.4 (only difference between two runs is different assumptions between Tables 5.1 and 10.4) and KASS projection of consumption needs.

that this area would be 50 percent in all cases. Thus, for example, with the same expected rate of yield increase at the experiment station, if the new technology has characteristics that would allow dissemination throughout the country, the expected rate of yield increase in Table 5.1 or Table 10.4 is doubled.

Thus far, we have assumed that the planned research results would be realized. As indicated earlier, the biological research enterprise involves much uncertainty or risk in terms of when and in what degree results will be realized. We have shown the consequences of realization of these research results optimistically. It seems logical to see what would happen if a planned research result is not realized.

For this purpose, we assume that the last three research outcomes specified in Table 5.1 to be zero for each crop in each region. The result, based on the medium policy level set, in addition to the assumption made above, is shown in Figure 10.3, together with the KASS projection of supply and need for consumption food grains. Note that the nation would not be able to attain food-self-sufficiency during the planning horizon considered here.

We do not intend to evaluate here overall performance of the economy if this pessimistic result to planned research outcome turns out true. But we do want to emphasize that there is no absolute and definite guarantee that this unfortunate phenomenon will not happen simply because it is unfortunate. There is certainly some chance for this unforuntate phenomenon to occur. But we cannot state its likelihood in terms of a probability.

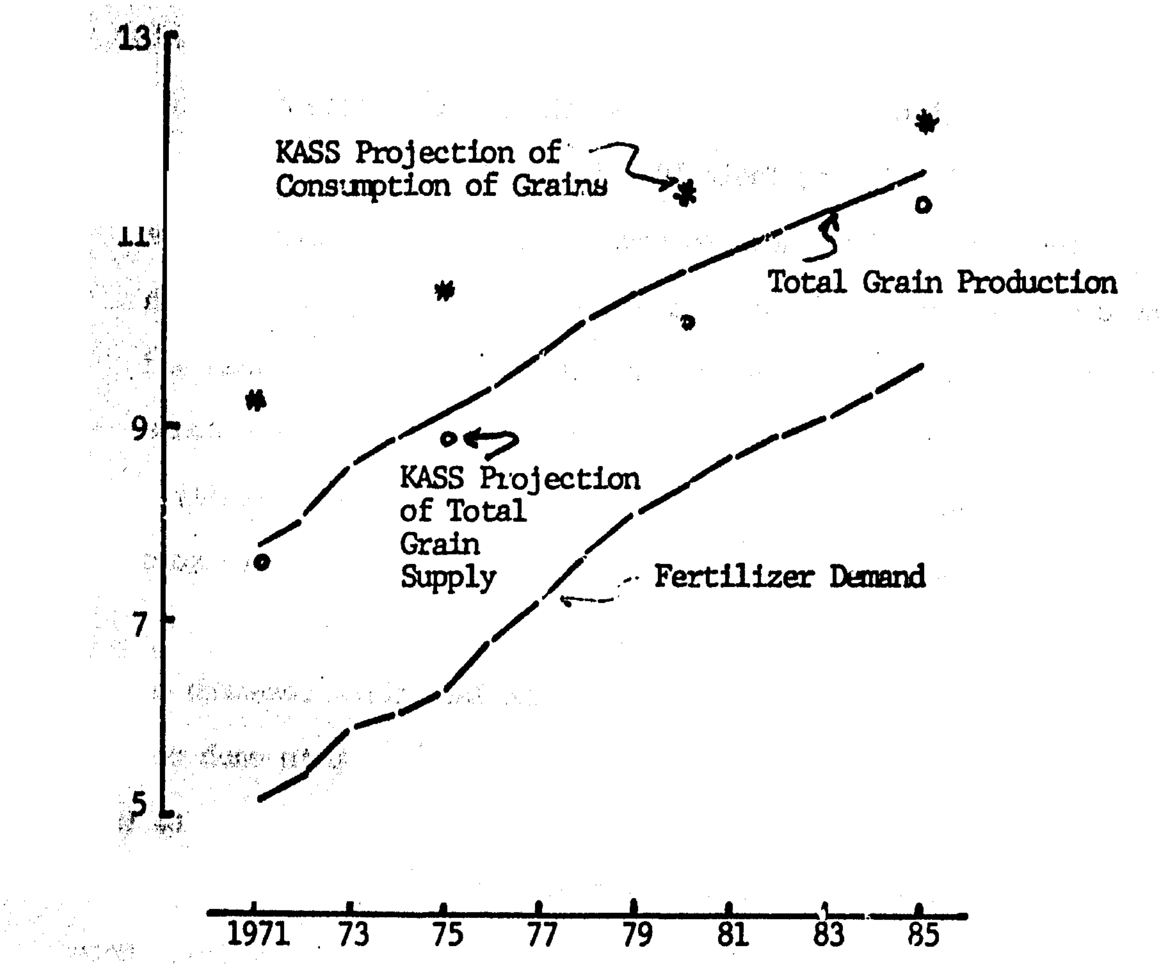

Figure 10.3. Total grain production, based on worst case of research outcome where last three research outcomes for each crop in each region are not realized and fertilizer demand based on above assumption, and KASS projection of consumption needs, and total grain supply.

We can glean something from this experiment. That is, as shown in Figure 10.3, first notice how closely total grain supply projection made by this model compares with that made by the KASS initial version. The major source of the difference between the two projections seems to originate from a difference in the initial condition. Second, demand by fertilizer would be growing slowly in contrast to the situation shown in Figure 10.1. This is because the seed and fertilizer or other materials are complementary to each other. Thus, in this situation, more production of fertilizer or other materials has little meaning except for export purposes.

What is the implication of these outcomes of the research enterprise? Let us assume that early attainment of food self-sufficiency is the important goal of Korean agricultural development. Then, all one can say in light of the above analysis, is to make a big push in research activity so that high levels of research outcome can be realized earlier and the uncertainty involved can be minimized.

Thus far, we have talked about research outcomes as a package. We will now examine the consequences of the degree of the research outcome for specific crops; as crops differ in terms of production consumption, and in the chance of attaining research outcomes. Rice is certainly the dominant crop in terms of production as well as consumption. We have already examined possible research outcomes for rice for a range in the accumulated rate of increase in rice productivity from 20 percent (which corresponds to the last policy run) to 50 percent (which corresponds to the "higher" policy input level in Table 9.1).

For the small grains, including rice, the accumulated rate of productivity increase by means of crop breeding would be at best 10 percent per decade, according to past experience. This is the primary reason that IRRI 667 is called a "Green Revolution" variety. However, there are other crops that are easier to breed for high yields--potatoes, forages and vegetables belong to this category. We observe that the leading farmer's record of the yield level of sweet potatoes, for example, is more than 56 ton per hectare, which is about 17 tons of grain equivalent. This figure is more than four times the national average yield of potatoes (sweet and white), about five times that of rice and six or seven times that of barley. On the other hand, in Japan experiment results show that the yield of sweet potato can be increased to 168 tons per hectare, which is about 52 tons of grain equivalent, a record about 40 times the national average potato yield in Korea.

What are the implications of this? It implies that the national average potato yield can be greatly increased by breeding or improving cultural practices or both. Based on this, we conducted another experiment. It's design is shown in Table 10.5. Possibility I assumes potato yield can be doubled and Possibility II trebled during the planning horizon.

The result is shown in Figure 10.4, together with total grain production projection, based on the pessimistic prediction for research outcomes discussed before and the KASS projection of consumption needs for grains. For comparison purposes in this policy run, we have assumed that the research outcome for the other crop is the same as ble 10.5. Hypothetical Planned Expected Research Results for Sweet and White Potatoes, in Terms of the Rate of Increase in Experiment Stations Yield, Adjusted by the Proportion of Crop Area that Could Advantageously Use Result.

Year	Possibility I	Possibility II
1971	0.05	0.05
1974	0.30	0.60
1977	0.40	0.90
1980	0.15	0.30
1983	0.10	0.15
Total	1.0	2.0

that in the worst case. It is now clear that food self-sufficiency can be achieved by 1979 under Possibility II and by 1981 under Possibility I, whereas it is not achieved by 1985 under the pessimistic prediction for overall research outcomes. Thus, more emphasis on breeding or improving cultural practices for sweet and white potatoes or both is certainly one means of attaining food self-sufficiency goal of Korean agricultural development.

The possibility of attaining food self-sufficiency by introducing more potatoes into production a d consumption is examined elsewhere Lee (L.6) [1] However, we have to be careful in making policy recommendations. In order for potato to become a larger part of the Korean diet, directly or indirectly, several preconditions must be met.

[1]The basic idea of this possibility is also in this author's unpublished comment on the KASS report.

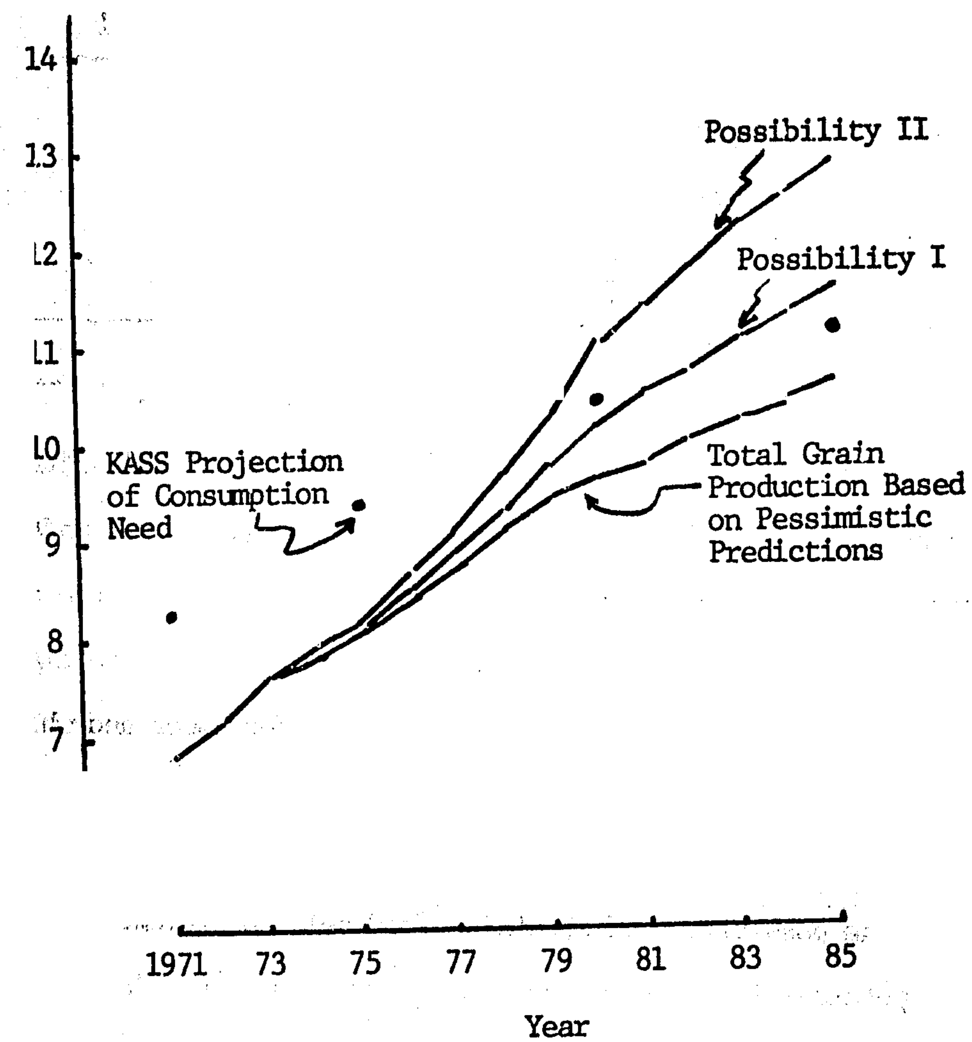

Figure 10.4. Total grain production projections, based on worst case on research outcomes, and on new experiment design in Table 10.5 where sweet and/or white potatoe yield is assumed doubled or tripled and KASS consumption need projection.

A high-yield technology must be produced; new methods of cooking processing and feeding livestock must be developed and adjusted to Korean taste; storage systems at the farm level as well as in the marketing process must be improved; edible oil sources must be developed and extended since edible oil is strongly complementary with potatoes (less for sweet than white) for cooking or processing, etc. None of these preconditions seems hard to attain, however. It seems that if the public decision-maker pays as much attention to these problems as he did to introducing more wheat products into the Korean diet (which is essentially a short-run solution to the food problem and not to income or other developmental problems which, furthermore, involves the potential danger of making Korea a permanent food import country), we can greatly increase the degree of food self-sufficiency and attain other development goals as well in the near future.

One possible bottleneck might be an adequate supply of edible oil. This author with others [K.1, L.8] also examined the possibility of increasing the edible oil supply from rape, which can be grown as a second crop with rice in the southwest provinces where the double crop ratio is comparatively low. Thus, rape oil production can be increased without significant curtailment of other crops such as barley.

Encouragement of more sweet and white potato production and consumption--directly or indirectly--would accelerate food processing and livestock production, while reducing the need for imports of food and feed grains and, hence, foreign exchange drains. In this process, income and employment opportunities would be generated or expanded. This author and others [L.7] examined the possibility of replacing feed grain with sweet potato silage by using a production function approach and concluded that this is an important possibility. The same idea was tested for a typical farm base using a linear programming framework [Lee (L.5)], and it was concluded that under the present structure of prices and yield technology for sweet and white potatoes, it was not profitable to transform potatoes into meat.

The possibility of transforming potatoes into meat and increasing the double crop ratio can be examined better when the component model presented in this study is linked with the farm resource allocation component of the KASS model.

In summary of the policy experiments, we examined a number of policy alternatives for attaining food self-sufficiency as a development goal. We stressed the complementary relationships among major instrumental policy or economic variables. At the same time, we emphasized that the means of achieving this food self-sufficiency goal must be consistent with attaining otherdevelopment goals such as income level and employment opportunity. The key variable seems to be seed technology, which must not be a once-and-for-all change, but rather must be evolutionary in nature, as Barker [B.1] suggests. However, it also seems that the research enterprise producing, new seed technology involves great risk and uncertainty. The national planning and food demand-supply budget is based on optimisitc outcomes for this risky enterprise will turn out to be the "tiger in the picture" in many instances.

This was true in the case of Hi-nong Il-ho (rice variety in mid-60s) and is partially true of IRRI-667

More seriously, committment of policy based on this unduly optimistic prediction has brought three major consequences to the nation's economy: (1) the wasting of scarce public budget, (2) the need for unexpected and large amounts of food grain imports and (3) price instability. We must have some provision for making a plan that involves less risk and uncertainty. We need a measure of security for a case when expected outcomes are unfortunately not realized. At any rate, we must establish a long-term policy with respect to food self-sufficiency that is consistent with attaining other development goals. This long-term policy must be able to provide the nation with a cheap balanced diet. The pattern and mainsprings of development must be sought in the land and people, and in the system of social and economic organization, as Kravis [K.7]suggests. The policy should not just imitate what the other countries are doing if their social and economic organization is different from ours.

Model Assumption Evaluation

Let us now evaluate the model. First, we want to evaluate some of its basic assumptions and its utility for planning purposes. As the reader remembers in Chapter VII, we adapted the profit-maximization assumption, which is often criticized as unrealistic. We admit the values sought in farming everywhere include more than money profit. When we neglect nonmonetary considerations, prediction based on the straightforward profit maximization assumption may well turn out to be unrealistic. This is a case proven by Wipe and Bawden [W.4].

Supply of elasticities are different, depending on whether or not capital budgets are considered, whether or not uncertainty is considered and whether or not provision is made for investment, disinvesement and resource fixity.

The profit-maximization assumption is not really wrong. The error is omission of nonprofit considerations. Johnson [J.16] writes that

> "This is not to state that all farmers are maximizers at all times under all conditions of risk and uncertainty. However, they do enough maximization so that theoretical maximizing models are useful in analyzing that part of their behavior having to do with response to price and resource allocation."

Second. in Chapter V, we failed to develop a theory relating biological research outcomes to public investment. Instead, we assumed a set of research outcomes with some possibility of materializing in specified magnitude of specified times, and then projected the consequences of each outcome. In a sense, this seems to have been the most unsuccessful part of our work. Heady [H.10] states that

> "Research and education are not purely stochastic phenomena with chance occurence relative to their initiation and outcome. . .The probability of scientific discovery for a particular product, function, or service depends on the quantity and quality of resources allocated to it."

However, as Jensen [J.1], among others, points out, "The economics of technological changes remains as one of the least developed areas in economics--both in theory and application." As repeatedly stated, biological research is risky and uncertain. Although we admit that the research outcomes are not purely a chance occurrence, we decided not to attempt to formulate a research production function, but, instead, to frankly recognize our inability to formulate such a function with reasonable accuracy; instead, we decided to project the possible consequences of alternative research outcomes with a simulation component.

Third, the reader may wonder why we need such complex models for innovation diffusion (Chapter V) or land and water development (Chapter IV). It is almost certain, for example, that a research outcome would eventually be adopted within, say five years. Is it not possible to model the diffusion process by a simple discrete difference equation with a five-year lag with due account of the discount factor? Such a model is appropriate when its purpose is to make a long-term projection, as did Black and Bonnen [B.8]. Our purpose has been to ask not only what will happen in, say, 1985, if certain public policy measures are adopted at the present time, but also to project the consequences year by year. In this situation, modeling by a simple difference equation is inadequate. As we noticed in the text, difference equations are a special case of the differential equations.

Further Study Needs

Before leaving this chapter, let us briefly discuss some future study needs. Throughout this report, especially at the end of each mathematical chapter and in the beginning of this chapter, we have indicated several areas for further study. Let us summarize these study needs.

First of all, about the model structure itself. We set up several tentative behavioral relationships. Examples include the farm consumption-saving-investment relationship, the noninstitutional private money market structure, the real price structure including the interest rate, etc. More understanding of the behavior of these economic variables is needed.

Second, as repeatedly indicated, the data base used in this study is tentative and weak. Even data on initial conditions fall in this category. For example, we took yield initial conditions for various crops by regions from publications that we know to have some inaccuracies. In the case of factor demand, our knowledge of initial conditions by crops and regions is poor. Technical or other behavioral coefficients are even worse. However, we have used theories or methodologies for estimating these coefficients from various data sources that are the best available to us at the present time. Constant attention to revision and use of better data is necessary. Standard econometrics or statistics will help us in estimating these parameters.

Third, there are inaccuracies in the model specification--that is, we assumed that once land is irrigated or the new seed adopted, productivity is instantaneously increased. For example, in the year following installation of irrigation structures, the yield level may not be the same as that on land where the structure was installed, say, five years ago. For long-run projection purposes, this assumption may not be bad and approximates the real world situation. However, for year-to-year projection, some provisions may be needed to account for this assumption.

Fourth, there are several other policy or environmental variables that might affect major output variables of this model. Examples include improvement in transportation and market systems, rural electrification or other infrastructures, and change in farm size and in migration patterns. Improvement in transportation, for example, will stimulate more regional specialization. This variable certainly has much to do with productivity growth, as illustrated by Johnson [J.3], among others. Nevertheless, the present version of the model fails to model this aspect accurately.

Lastly, model verification from historical data does not seem to be sufficient. However, this historical verification seems to fulfill a necessary condition. Due to constraints on data and time, we hesitated to undertake a broader attack on this task at the present time. However, this seems worthwhile to conduct to the extent that data are available.

In summary, we have written about further needs for improving the model presented here, to be more realistic and to do more and detailed policy analysis.

As indicated above, the version of the model presented here contains defects that indicate further study needs. Nevertheless, the version of the model presented here seems to represent the real world situation reasonably well; that is, the model seems to be capable of projecting yield levels and related conventional factor demand and projecting the consequences of various policy alternative in terms of relevant criterion variables. With further refinement the model can be useful in evaluating policy alternatives for the Korean agricultural development.

CHAPTER XI

SUMMARY

In this chapter, we briefly summarize objectives, structure and results of the model, and end with a few general remarks.

The primary purpose of this study has been to model part of the production system for Korean agriculture as a component of KASS model. Since the acreage response system was already built, we have concentrated on modeling the yield response, and hence, factor demands of various crops in different regions. The basic emphasis of this study, however, has been on explaining how public policies, programs and projects concerned with technological, institutional and human changes affect yield response.

It is concluded in this study that the major sources of productivity growth and economic development are structural changes generated largely by public policies, programs and projects. Thus, the basic task has been to determine the kind and levels of policy variables that contribute to attaining agricultural yield goals for Korean agriculture.

The specific objectives of this study were:

1. to project:

   a. total agricultural land by paddy land and upland, for each agricultural region over time.

   b. improved agricultural land area by irrigation, consolidation and drainage types for each agricultural region over time.

c. yield levels by crops and regions over time

d. conventional factor (fertilizer, pesticides and other materials) demand for each crop in each region over time

e. labor demand for each crop in each region in major labor peak seasons over time.

2. to identify the source of yield growth, including biological research results and their dissemination, and

3. to evaluate public policies, projects and programs in terms of attaining development goals.

One important intermediate purpose of this study has been to show empirically how different disciplinary theories and techniques can be used together to model a complex system more precisely and accurately. That is, after recognizing that one of the primary purposes of economic development policy is to alter input-output coefficients in agricultural production, we have tried to internalize the production rate and, hence, factor demand, which is subject to various levels of the public policies and other economic opportunities, by using a systems simulation approach. The results of this model are to be fed into the agricultural resource allocation component of th KASS, which is a type of linear programming model that assumes a fixed input requirement in producing a given amount of output. Some neoclassical economic (modified or unmodified) development and growth theories are incorporated in this model.

The systems simulation approach has proven useful in solving practical problems involving system complexity, lagged adjustment, feed back and forth, uncertainty, and situations where few time series data are availabl and for which the classical economic models are not very adequate.

Tyner and Tweeten [T.7] put this matter in this way:

> "Relationships between variables in agriculture and between agriculture and the nonagricultural sector are complex and dynamic and are not always suited to analysis by conventional optimizing quantitative techniques. Quantitative procedures are needed which can include time lags, nonlinearity, and secondary and tertiary effects over a reasonably long period of time The simulation procedure meets these requirements and allows the recursive aspects of the agricultural processes to be mostly effectively portrayed."

Economic development in agriculture is a complex process. Equally complex sets of policy instruments are required to affect transformation of traditional agriculture. Thus, the model dealing with this complex system must be complex enough to measure important possible repercussions of policy inputs. Therefore, we have tried to meet comprehensiveness, consistency and optimality criteria in a sector model for planning purposes.

In structuring the model, we specified a Cobb-Douglas type production function for every crop in each region under consideration. We have two basic inputs: conventional inputs and structural change variables, which enact to shift the yield function as well as the factor demand function. There are three different structural change variables. The first involves biological technology and human change through extension of biological research. The second has to do with land and water development (three types of paddy land irrigation, land consolidation for paddy as well as for upland, paddy drainage, upland irrigation and consolidation, and upland and tideland development). The third is the variable typically and exclusively related to perennial crop production such as tree crop age composition and residual effect of the conventional inputs used in the past. The first two structural change variables are generated mainly by th public sector. The rate of land improvement has been modeled by a high-order differential equation as a function of public investment, among others. The same is true for the biological research and dissemination of its results, but we have recognized the existence of indigenous innovation among leading farmers and by numbers of the agribusiness sector. All independent variables in our production function except the conventional inputs have been internally generated according to specified public policies.

Instead of trying to specify a research production function for public investments, we specified a set of possible biological research results for each crop in each region over time. It is assumed that biological research results can be attained by the public sector within the limits of known scientific methods and knowledge through direct public investment. It also involves institutional reform. Since biological research involves biological processes, results are subject to uncertainty. Further there is doubt as to whether the traditional concepts of a production function applies to research programs; this was a basic reason for not trying to specify a research production function. Instead, we constructed the model (Chapter V) so that consequences of alternative biological research results could be simulated to determine the impact of possible outcomes on various performance variables for the agricultural sector.

To project input usage for conventional production factors, we have derived factor demand functions from commodity production functions with an assumption of profit maximization. In doing this, we have considered several behavioral constraints. First, we have imposed a capital budget constraint with a stepped supply function for credit. Thus, government policies on credit and interest rate have explicitly become one type of policy variable. Second, factor demand elasticities have been adjusted, based on the direction, duration and magnitude of prices of both products and factors. It is also allowed that an economic adjustment in the sector can take place, based on changes in regional specialization, long-term profitability and others. In connection with this, there are two major policy variables: product prices and production factor prices.

We have computed the marginal internal rate of return to capital with a given supply of capital. The demand function for capital is derived from the budget constraint equation, after each independent variable has been replaced with the relevant constrained factor demand function for all factors and crops in each region. We have secured all relevant first-order conditions for optimaltiy, and all relevant consistency relationships known as the Fresch scheme [F.12]. In computing the marginal rate of return to capital, since there is no analytical solution, we used an iterative numerical method. Since the supply function of capital is a stepped function, we determined whether or not a given supply of capital is fixed, by comparing the marginal rate of return to capital with appropriate interest rates. For farmer-owned capital, we assumed the farmer can dispose of part of it when the internal rate is less than that he can earn by using other than in farming. When the internal rate of return is higher than the off-farm opportunity cost, we determined whether or not credit could be borrowed at a higher interest rate.

Once the marginal rate of return to capital was known, it was a mechanical process to predict the optimal input rate, and hence the output rate, since we already had all relevant functions, parameters, market or policy variables, and structural variables previously generated by the public investment. Notice again that the production response was exclusively the consequence of factor use and the behavi of function shifters. Then we were again ready to compute the relevant aggregate variables. In some cases, we have used the area allocated to each crop projected by the KASS initial version of policy alternative II.

We assumed that labor inputs were not a limiting factor of production; on the other hand, structural change variables were assumed to be labor requirement function shifters. Many public investment programs defined above are designed to save labor. Aggregate agricultural labor use will be determined by the level of mechanization when this model component is linked with the farm resource allocation component of the KASS model.

Production elasticities with respect to the conventional production factors have been estimated by the factor share technique, which is estimated by a method similar to that suggested by Tyner and Tweeten [T.6]. In other words, factor shares have been estimated from the distributed lag prices and input and output rates. The demand elasticities for the conventional inputs have been derived from the production function. Other production parameters have been estimated separately, using various techniques and various sources of data.

After testing the model to determine whether it works properly, through a series of sensitivity analyses, we designed policy experiments involving different levels of public investment for land and water development, different price policies for products and production factors, different policies on interest rates, and several sets of possible research outcomes. We made computer runs for each level of each policy variable and several different combinations of policy variable levels.

Results of our work are as follows: First of all, we have quantitatively and formally identified the sources of productivity growth for each crop in each region in more detail and precision than any study has achieved thus far--that is, we computed how much each of the structural change variables and conventional inputs increase yields for each crop in each region over time.

Major Conclusions

The major conclusions drawn from the policy experiments can be summarized as follows:

First, complementary relationships exist among the so-called conventional inputs, between these inputs and structural change variables, and between these technological inputs and variables governing farmer incentives. The major determinants of the conventional inputs, especially fertilizer, seem to be: (1) varietal change and (2) land and water development. Without these changes, there seems limited room for fertilizer to contribute to yield growth.

Second, it appears that biological technology is certainly the most critical factor determining growth in yields. Without such advance, the contribution of the conventional inputs to growth is certainly less than with it. Hence, policies on product and production factor prices and on government credit and its interest rates can play only a limited role in increasing crop yield when there is little advance in technological change. This seems to stem from the fact that the Korean farmer presently uses nearly optimum levels of conventional inputs with a given technology. In this situation, a "positive" price policy [Krishna(K.10)] may not encourage farmers to use more of the conventional inputs, although a "negative" price policy has a danger of reducing used conventional inputs.

The second most important structural change variable to productivity growth was found to be irrigation. However, the Korean irrigation system is fairly well developed. For example, the paddy area under the Irrigation Association (termed the perfectly irrigated paddy in this thesis) is about 40 percent in each region. Suppose that: (1) this paddy area increases to 60 percent by 1985 and (2) the production elasticity is 0.2. Then total yield productivity growth due to this land improvement project by 1985 would be 10 percent when the complementary input is adequately supplied.

On the other hand, we should not evaluate public investments only in terms of yield productivity, since public investments achieve multiple purposes, such as reducing uncertainty in production, reducing labor requirement, etc., in addition to yield increase. The other important structural change variable defined in this model is found to be age composition change for tree crops.

In summary, it appears that there is an interaction effect between varietal change and water or land improvement, and between land and water improvement. However, the model presented in this study has failed to appropriately account for this interaction effect.

The number of values to be attained in developing Korean agriculture is certainly more than one. Customarily, the degree of development is measured in terms of total production of food, income levels and distribution, and employment. This study cannot be fully evaluated in terms of these and other performance variables unless the model presented in this study is linked with the rest of the KASS model. We have tentatively evaluated alternative policies in terms of physical production as one of the most important development values for Korean agriculture to be food self-sufficient. Bread is certainly not sufficient for modern living but without it nobody can live.

In assessing the degree of food self-sufficiency, we have assumed that producer prices, area allocated to each crop, and the consumption needs projected by the initial version of the KASS model would correctly represent the future.

Food grain is assumed to be composed of rice, barley, wheat, other grains, pulses and potatoes and production levels for each are measured in terms of grain equivalent. Since biological technology involving varietal change is a most crucial factor for productivity growth, we have made several alternative assumptions as to research outcomes and have then simulated to project the consequences.

In connection with this policy experiment, we have concluded that Korea is not likely to achieve food-self-sufficiency before 1980. In the case of the worst biological research outcomes studied, Korea would not be able to attain this goal even by 1990.

Assuming that early attainment of food self-sufficiency is one of the most desirable goals, we have tried to identify some measures to achieve it. For this purpose, we have made two additional polic experiment runs. The first one was based on some notion of "big push" in biological research activities such that greater biological research output can be realized earlier; that experiment result has shown that the food self-sufficiency goal could be attained in late 1970s.

The second policy experiment was formulated on the basis of the following:

(1) The leading and crucial source of yield productivity growth, biological research, involves a good deal of risk and uncertainty in terms of when and how much production is made available.

(2) In the case of small grains such as rice, barley, wheat, etc., productivity gains by means of breeding would be, at best, 10 percent per decade, according to past experience.

(3) The potential productivity gain is different, depending on genetic nature of the specific crop, for example, yields of potatoes, vegetables, forage crops and so on can easily be increased through improvements in varieties and cultural practices or both.

Especially well known as a crop with a great potential to produce with a given resource is the potato. Potato yields can be doubled or even tripled by improving the variety and cultural practices.

On the other hand, it is known that per capita consumption of potatoes in Korea is much lower than in Euroepan or some other developed countries. Potato consumption in Korea could be greatly increased if: (1) potatoes can be produced more cheaply through technological change in production, and (2) potatoes are processed in forms adjusted to Korean tastes. This involves improving cooking and processing methods.

Potatoes can be processed either at factory or through livestock. That is, potatoes can be transformed into meat or milk. Once potato yields are greatly increased, potatoes can become a good substitute for concentrate feeds.

Along this line, we have made other alternative assumptions on possible biological research to investigate the consequences of improving the variety and cultural practices for potatoes. We have designed two experiments. First, potato yield is doubled, and second, it is tripled through biological research during the planning horizon under consideration (1971-1985). For both experiments, we assumed biological research outcomes for the crops would be the lowest one we examined before. The experimental result shows that total grain equivalent needs projected by the KASS model can be produced domestically by 1978-79 under an assumption tripled potato yields, and by 1981-82 under the assumption of doubled potato yields.

Improving cooking or processing methods for potatoes involves several problems. It requires an adequate supply of edible oil, which may be fulfilled by encouraging rape production using idle winter land in the southwest provinces. Also required are research and extension for improving cook methods and for using potatoes as feeds.

On the other hand, the policy alternative encouraging more production and consumption of potatoes has other advantages, too: (1) the double cropping ratio can be increased, especially in the southern provinces, by producing either more white potatoes or rape. (2) The transformation of potatoes into meat or milk would generate more income and employment, and (3) depending on the degree of self-sufficiency attained, imports of food and feed grains can be reduced and foreign exchange saved.

The conclusions reached here should be interpreted with reservations. This is so partially because various levels of interactions with other sectors or subsectors of Korean economy are not fully taken into consideration as this model component has not been incorporated into the total model and because the data base of the model is rather weak. Needless to say, the projections this model makes and its use in the evaluation of public policies, projects and programs will be improved when this component model is linked with the rest of the KASS model. In the earlier chapters, we discussed limitation of the present model and further study needs for improving it. This has to do with: (1) data improvement, (2) refinement of some model structures, and (3) linkage with other components of the KASS model.

Nevertheless, the version of the model presented here seems to represent the real world situation reasonably well; that is, the model seems to be capable of projecting yield levels and related conventional factor demand and projecting the consequences of various policy alternatives in terms of relevant criterion variables. With further refinement the model can be useful in evaluating policy alternatives for Korean agricultural development.

APPENDIX A

COMPUTER PROGRAM

```
      PROGRAM MAIN (INPUT, OUTPUT)                                      MAIN       2
      COMMON /CONTR/  DT,DTP,DTY,FINEDT,IALT,IALTEX(3),IDT,IPCSD,       CONTR      2
     1                IDROTH,IPRP(6),IPRPRD,IRUN,ISENS,ITIME,IYEAR,     CONTR      3
     2                JPER,NCUM,NCROP,NDTPOP,NTDPR2,NREGN,NRUN,NT,      CONTR      4
     3                NTIME,NYEARS,NYRPR2,T,YEAR,YEARAG,YEARO,NCOMAG    CONTR      5
      COMMON /VAIC/ FXDM1(3,13,3), FX(3,13,3),  FXD(3,13,3),PXD(3,3),   VAIC       2
     1              IHEXYR(3,13,5),PD(3,13),    YD(3,13),    ACTC(3,13), VAIC       3
     2              GZSTH1(3,13),  RAM(3),      UCIS(3),     BEKD(3,13), VAIC       4
     3              AMP(3,13,5),   FLBD(3,13,2),PITP1(3),    PITP2(3),   VAIC       5
     4              TSP(3,13,5),   PROFTY(3,13),PITP3(3),    PITP4(3),   VAIC       6
     5              TDP(3,13,5),   CSLP(3),     PIT1(3),     PIT2(3),    VAIC       7
     6              RGA1(5,13,5),  DRDP(3),     PIT3(3),     PIT4(3),    VAIC       8
     7              RGA2(5,13,5),  UCSUL(3),    D1TP(3,4),   D2TP(3,4),  VAIC       9
     8              RGA3(5,13,5),  RCP(3),     RDP(3),       RCU(3),     VAIC      10
     9              DGA(3,13,5),   RIU(3),      RTD(3),      RUD(3),     VAIC      11
     1              RINT(5,3,8),   STRGP(3,8),  DSC(3,8),    S(3,8),     VAIC      12
     2              CSUL(3),       ULIG(3),     TL(3,8),     GLIRD(3)    VAIC      13
      COMMON /PTSF/ PAVG(3,13),  A(3,13),     TA(3),        PX(3,3),     PTSF       2
     1              ASOP(13),    SZC(3,13),   RSP(3,13),    AGREV(3,13), PTSF       3
     2              PXDM1(3,3),  PDM1(3,13),  TLAND(3),     YZP(3,13),   PTSF       4
     3              ACTCM1(3,13),SCR(3,7),    APSC(3,8),    WAP(3,2),    PTSF       5
     4              SLDR(3,2),   STLAND,      STA,          SAGREV(3)    PTSF       6
      COMMON /VPRT/ TPLAND(3),  TULAND(3),  TCPA(3,8),  SFUCEY(3,13),    VPRT       2
     1              TCPD(3,8),  GTZS(3,13), GZS(3,13),  PIEYLD(3,13),    VPRT       3
     2              GZ(3,13,5), GTZ(3,13,5),TREV(3),    ACEYYY(3,13),    VPRT       4
     3              TVC(3),     CC(3),      TPCOST(3),  YZDYYY(3,13),    VPRT       5
     4              TNFIN(3),   TPP(3,13),  STPP(13),   SCEYYY(3,13),    VPRT       6
     5              TFOK(3),    TGL(3),     TPVL1(3),   SYNLAN(3,13),    VPRT       7
     6              TPVL2(3),   YLD(3,13),  AYLD(13),   AFX(13,3),       VPRT       8
     7              ATFLB(13),  AFLB(13,2), TFLB(3,13), FLB(3,13,2),     VPRT       9
     8              STREV,      STVC,       SUCIS,      SCC,             VPRT      10
     9              STCOST,     STNFIN,     STFOK,      STGL,            VPRT      11
     1              STPVL1,     STPVL2,     SFXO(3,13),  SSFXO(3),       VPRT      12
     2              SSFX(3),    FOK(3),     GL(3),       PVL1(3),        VPRT      13
     3              PVL2(3)                                              VPRT      14
      T = 0.0                                                           MAIN       7
      CALL INPMFP                                                       MAIN       8
      YEAR = 1970.0                                                     MAIN       9
      DT = 1.0                                                          MAIN      10
      DO 700 I=1,15                                                     MAIN      11
      CALL PURINV                                                       MAIN      12
      CALL TEMP                                                         MAIN      13
      CALL SOCDIF                                                       MAIN      14
      CALL FDYLD                                                        MAIN      15
      T = T + DT                                                        MAIN      16
      PRINT 94,T                                                        MAIN      17
   94 FORMAT (* TIME = *,F10.2)                                         MAIN      18
      YEAR = YEAR + DT                                                  MAIN      19
  700 CONTINUE                                                          MAIN      20
      END                                                               MAIN      21
```

```
      SUBROUTINE INPHFP                                                 INPHFP     2
      COMMON /VAIC/ FXDM1(3,13,3), FX(3,13,3),  FXD(3,13,3),PXD(3,3),   VAIC       2
     1              IBEXYR(3,13,5),PD(3,13),    YD(3,13),   ACTC(3,13), VAIC       3
     2              QZSTH1(3,13),  RAM(3),      UCIS(3),    BEXD(3,13), VAIC       4
     3              AMP(3,13,5),   FLBD(3,13,2),PITP1(3),   PITP2(3),   VAIC       5
     4              TSP(3,13,5),   PROFTY(3,13),PITP3(3),   PITP4(3),   VAIC       6
     5              TDP(3,13,5),   CSLP(3),     PIT1(3),    PIT2(3),    VAIC       7
     6              RGA1(5,13,5),  DRDP(3),     PIT3(3),    PIT4(3),    VAIC       8
     7              RGA2(5,13,5),  UCSUL(3),    D1TP(3,4),  D2TP(3,4),  VAIC       9
     8              RGA3(5,13,5),  RCP(3),      RDP(3),     RCU(3),     VAIC      10
     9              DGA(3,13,5),   RIU(3),      RTD(3),     RUD(3),     VAIC      11
     1              RINT(5,3,8),   STRGP(3,8),  DSC(3,8),   S(3,8),     VAIC      12
     2              OSUL(3),       ULIG(3),     TL(3,8),    GLIRD(3)    VAIC      13
      COMMON /PTSF/ PAVG(3,13),  A(3,13),      TA(3),      PX(3,3),     PTSF       2
     1              ASOR(13),    SZC(3,13),    RSP(3,13),  AGRBV(3,13), PTSF       3
     2              PXDM1(3,3),  PDM1(3,13),   TLAND(3),   YZD(3,13),   PTSF       4
     3              ACTCM1(3,13),SCR(3,7),     APSC(3,8),  WAP(3,2),    PTSF       5
     4              SLDR(3,2),   STLAND,       STA,        SAGREV(3)    PTSF       6
      COMMON /VPRT/ TPLAND(3),  TULAND(3),  TCPA(3,8),  SFUCEY(3,13),   VPRT       2
     1              TCPD(3,8),  QTZS(3,13), GZS(3,13),  PIEYLD(3,13),   VPRT       3
     2              QZ(3,13,5), QTZ(3,13,5),TREV(3),    ACEYYY(3,13),   VPRT       4
     3              TVC(3),     CC(3),      TPCOST(3),  YZDYYY(3,13),   VPRT       5
     4              TNFIN(3),   TPP(3,13),  STPP(13),   SCEYYY(3,13),   VPRT       6
     5              TFOK(3),    TGL(3),     TPVL1(3),   SYNLAN(3,13),   VPRT       7
     6              TPVL2(3),   YLD(3,13),  AYLD(13),   AFX(13,3),      VPRT       8
     7              ATFLB(13),  AFLB(13,2), TFLB(3,13), FLB(3,13,2),    VPRT       9
     8              STREV,      STVC,       SUCIS,      SCC,            VPRT      10
     9              STCOST,     STNFIN,     STFOK,      STGL,           VPRT      11
     1              STPVL1,     STPVL2,     SFXQ(3,13),  SSFXQ(3),      VPRT      12
     2              SSFX(3),    FOK(3),     GL(3),       PVL1(3),       VPRT      13
     3              PVL2(3)                                             VPRT      14
                                                                        INPHFP     6
ITIAL CONDITIONS                                                        INPHFP     7
 PITP1 (1) = 0.24985                                                    INPHFP     8
 PITP1 (2) = 0.25734                                                    INPHFP     9
 PITP1 (3) = 0.17837                                                    INPHFP    10
 PITP2 (1) = 0.41492                                                    INPHFP    11
 PITP2 (2) = 0.42343                                                    INPHFP    12
 PITP2 (3) = 0.50571                                                    INPHFP    13
 PITP3 (1) = 0.21292                                                    INPHFP    14
 PITP3 (2) = 0.20395                                                    INPHFP    15
 PITP3 (3) = 0.20798                                                    INPHFP    16
 PITP4 (1) = 0.12231                                                    INPHFP    17
 PITP4 (2) = 0.11528                                                    INPHFP    18
 PITP4 (3) = 0.10794                                                    INPHFP    19
 PIT1(1) =  86.73653                                                    INPHFP    20
 PIT1(2) = 199.06203                                                    INPHFP    21
 PIT1(3) =  23.72267                                                    INPHFP    22
 PIT2(1) = 153.74996                                                    INPHFP    23
 PIT2(2) = 329.94911                                                    INPHFP    24
 PIT2(3) =  69.97614                                                    INPHFP    25
 PIT3(1) =  65.16855                                                    INPHFP    26
 PIT3(2) = 138.38831                                                    INPHFP    27
 PIT3(3) =  23.81823                                                    INPHFP    28
 PIT4(1) =  35.98875                                                    INPHFP    29
 PIT4(2) =  66.94875                                                    INPHFP    30
 PIT4(3) =  11.61405                                                    INPHFP    31
 CSLP(1) =  44.79634                                                    INPHFP    32
 CSLP(2) =  96.27462                                                    INPHFP    33
 CSLP(3) =  16.93167                                                    INPHFP    34
 DRDP(1) = 273.31504                                                    INPHFP    35
```

```
DRDP(2) = 587.39856
DRDP(3) = 103.30488
UCSUL(1) = 217.8211
UCSUL(2) = 472.1126
UCSUL(3) = 236.5707
D1TP(1,1) = 0.44975
D1TP(1,2) = 0.26530
D1TP(1,3) = 0.0
D1TP(1,4) = 0.0
D1TP(2,1) = 0.83525
D1TP(2,2) = 0.49270
D1TP(2,3) = 0.0
D1TP(2,4) = 0.0
DO 5 L = 1,4
D1TP(3,L) = 0.0
D2TP(1,1) = 1.80723
D2TP(1,2) = 3.17264
D2TP(1,3) = 3.04464
D2TP(1,4) = 3.24949
D2TP(2,1) = 3.91854
D2TP(2,2) = 6.87910
D2TP(2,3) = 8.55301
D2TP(2,4) =11.38313
D2TP(3,1) = 1.96354
D2TP(3,2) = 3.44705
D2TP(3,3) = 4.28582
D2TP(3,4) = 5.70397
BCP   (1) = 0.1
BCP   (2) = 0.1
BCP   (3) = 0.1
BDP   (1) = 0.78
BDP   (2) = 0.78
BDP   (3) = 0.78
BCU   (1) = 0.0
BCU   (2) = 0.0
BCU   (3) = 0.0
BIU   (1) = 0.0
BIU   (2) = 0.0
BIU   (3) = 0.0
BTD   (1) = 0.00193
BTD   (2) = 0.00169
BTD   (3) = 0.0
BUD   (1) = 0.05761
BUD   (2) = 0.03934
BUD   (3) = 0.05841
DO 6 I = 1,3
CSUL(I) = 0.0
ULIG(I) = 0.0
DO 6 K = 1,8
S(I,K) = 0.0
TL(I,K) = 0.0
STRGP(I,K) = 0.0
DO 7 L = 1,5
DSC(I,L+3) = 0.0
BINT(L,I,K) = 0.0
CONTINUE
CONTINUE
STRGP(1,3) = 11.7152
STRGP(2,3) = 27.6703
STRGP(3,3) =  4.8116
STRGP(1,4) = 11.6270
```

```
      STRGP(2,4) = 13.4876
      STRGP(3,4) =  1.0174
      DO 8  L = 1,5
      RINT(L,1,3) = 4.68608
      RINT(L,2,3) = 11.06812
      RINT(L,3,3) = 1.92464
      RINT(L,1,4) = 7.75137
      RINT(L,2,4) = 8.99177
      RINT(L,3,4) = 0.67827
      DO 4 I = 1,3
      DO 4 K = 1,8
    4 DSC(I,K) = RINT(1,I,K)
C  FACTOR USED IN 1970 , MILLION WON PER 1000 HA
      DO 10 I = 1,3
      GLIRD(I) = 0.08
      FX(I,1,1) = 11.830
      FX(I,1,2) =  3.310
      FX(I,1,3) =  6.040
      FX(I,2,1) = 15.615
      FX(I,2,2) =  1.28
      FX(I,2,3) =  4.850
      FX(I,3,1) = 13.720
      FX(I,3,2) =  1.28
      FX(I,3,3) =  3.470
      FX(I,4,1) =   6.60
      FX(I,4,2) =   1.28
      FX(I,4,3) =  0.94
      FX(I,5,1) = 24.270
      FX(I,5,2) =   80.064
      FX(I,5,3) = 62.890
      FX(I,6,1) =  5.330
      FX(I,6,2) =  1.920
      FX(I,6,3) =  1.590
      FX(I,7,1) = 30.225
      FX(I,7,2) =  4.062
      FX(I,7,3) =  7.202
      FX(I,8,1) = 16.225
      FX(I,8,2) =  3.595
      FX(I,8,3) =  1.505
      FX(I,9,1) = 17.54
      FX(I,9,2) =  2.760
      FX(I,9,3) = 46.62
      FX(I,10,1) = 5.330
      FX(I,10,2) = 1.920
      FX(I,10,3) = 1.590
      FX(I,11,1) = 24.270
      FX(I,11,2) =  4.700
      FX(I,11,3) =40.52
      FX(I,12,1) = 11.635
      FX(I,12,2) =  1.930
      FX(I,12,3) =  3.360
      FX(I,13,1) =  0.266
      FX(I,13,2) =  0.05
      FX(I,13,3) =  0.15
      FXD(I,1,1) = 11.830
      FXD(I,1,2) =  3.310
      FXD(I,1,3) =  6.040
      FXD(I,2,1) = 15.615
      FXD(I,2,2) =  1.28
      FXD(I,2,3) =  3.480
      FXD(I,3,1) = 13.720
```

```
      FXD(I,3,2) =  1.28                                                INPMFP 158
      FXD(I,3,3) =  3.470                                               INPMFP 159
      FXD(I,4,1) =   6.30                                               INPMFP 160
      FXD(I,4,2) =  1.28                                                INPMFP 161
      FXD(I,4,3) =   0.94                                               INPMFP 162
      FXD(I,5,1) = 24.270                                               INPMFP 163
      FXD(I,5,2) = 80.064                                               INPMFP 164
      FXD(I,5,3) = 62.890                                               INPMFP 165
      FXD(I,6,1) =  5.330                                               INPMFP 166
      FXD(I,6,2) =  1.920                                               INPMFP 167
      FXD(I,6,3) =  1.590                                               INPMFP 168
      FXD(I,7,1) = 30.225                                               INPMFP 169
      FXD(I,7,2) =  4.062                                               INPMFP 170
      FXD(I,7,3) =  7.202                                               INPMFP 171
      FXD(I,8,1) = 16.225                                               INPMFP 172
      FXD(I,8,2) =  3.595                                               INPMFP 173
      FXD(I,8,3) =  1.505                                               INPMFP 174
      FXD(I,9,1) = 17.54                                                INPMFP 175
      FXD(I,9,2) =  2,760                                               INPMFP 176
      FXD(I,9,3) = 46.62                                                INPMFP 177
      FXD(I,10,1) = 5.330                                               INPMFP 178
      FXD(I,10,2) = 1.920                                               INPMFP 179
      FXD(I,10,3) = 1.590                                               INPMFP 180
      FXD(I,11,1) =  24.27                                              INPMFP 181
      FXD(I,11,2) =  4.700                                              INPMFP 182
      FXD(I,11,3) = 40.52                                               INPMFP 183
      FXD(I,12,1) = 11.635                                              INPMFP 184
      FXD(I,12,2) =  1.930                                              INPMFP 185
      FXD(I,12,3) =  3.360                                              INPMFP 186
      FXD(I,13,1) =  0.266                                              INPMFP 187
      FXD(I,13,2) =  0.05                                               INPMFP 188
      FXD(I,13,3) =  0.15                                               INPMFP 189
      FXDM1(I,1,1) = 11.830                                             INPMFP 190
      FXDM1(I,1,2) =  3.310                                             INPMFP 191
      FXDM1(I,1,3) =  6.040                                             INPMFP 192
      FXDM1(I,2,1) = 15.615                                             INPMFP 193
      FXDM1(I,2,2) =  1.28                                              INPMFP 194
      FXDM1(I,2,3) =  3.480                                             INPMFP 195
      FXDM1(I,3,1) = 13.720                                             INPMFP 196
      FXDM1(I,3,2) = 1.28                                               INPMFP 197
      FXDM1(I,3,3) =  3.470                                             INPMFP 198
      FXDM1(I,4,1) =  6.60                                              INPMFP 199
      FXDM1(I,4,2) =  1.28                                              INPMFP 200
      FXDM1(I,4,3) =  0.94                                              INPMFP 201
      FXDM1(I,5,1) = 24.270                                             INPMFP 202
      FXDM1(I,5,2) =  80.064                                            INPMFP 203
      FXDM1(I,5,3) =  62.890                                            INPMFP 204
      FXDM1(I,6,1) =   5.330                                            INPMFP 205
      FXDM1(I,6,2) =   1.920                                            INPMFP 206
      FXDM1(I,6,3) =   1.590                                            INPMFP 207
      FXDM1(I,7,1) =  30.225                                            INPMFP 208
      FXDM1(I,7,2) =   4,062                                            INPMFP 209
      FXDM1(I,7,3) =   7,202                                            INPMFP 210
      FXDM1(I,8,1) = 16.225                                             INPMFP 211
      FXDM1(I,8,2) =  3.595                                             INPMFP 212
      FXDM1(I,8,3) =  1.505                                             INPMFP 213
      FXDM1(I,9,1) = 17.54                                              INPMFP 214
      FXDM1(I,9,2) =  2.760                                             INPMFP 215
      FXDM1(I,9,3) = 46.62                                              INPMFP 216
      FXDM1(I,10,1) = 5.330                                             INPMFP 217
      FXDM1(I,10,2) = 1.920                                             INPMFP 218
```

```
      FXDM1(I,10,3) = 1.590
      FXDM1(I,11,1) = 24.27
      FXDM1(I,11,2) =  4.700
      FXDM1(I,11,3) = 40.52
      FXDM1(I,12,1) = 11.635
      FXDM1(I,12,2) =  1.930
      FXDM1(I,12,3) =  3.360
      FXDM1(I,13,1) =  0.266
      FXDM1(I,13,2) =  0.05
      FXDM1(I,13,3) =  0.15
      PXD(I,1) = 1.0
      PXD(I,2) = 1.0
      PXD(I,3) = 1.0
      PD(I,1) = 68.88
      PD(I,2) = 42.95
      PD(I,3) = 24.30
      PD(I,4) = 36.60
      PD(I,5) = 50.65
      PD(I,6) = 80.66
      PD(I,7) = 41.51
      PD(I,8) = 49.15
      PD(I,9) = 187.27
      PD(I,10) = 8.5
      PD(I,11) = 406.46
      PD(I,12) = 146.42
      PD(I,13) = 4.5
10    CONTINUE
      YD(1,1) = 3.48533
      YD(1,2) = 1.90417
      YD(1,3) = 2.22546
      YD(1,4) = 0.72301
      YD(1,5) = 5.91284
      YD(1,6) = 0.75956
      YD(1,7) = 9.75803
      YD(1,8) = 3.70138
      YD(1,9) = 1.41647
      YD(1,10) = 25.0
      YD(1,11) = 0.26062
      YD(1,12) = 0.69119
      YD(1,13) = 6.0
      YD(2,1) = 3.34850
      YD(2,2) = 2.25734
      YD(2,3) = 2.30959
      YD(2,4) = 0.71409
      YD(2,5) = 8.90738
      YD(2,6) = 0.70748
      YD(2,7) = 11.38854
      YD(2,8) = 4.33351
      YD(2,9) = 1.43990
      YD(2,10) = 25.0
      YD(2,11) = 0.27378
      YD(2,12) = 0.95661
      YD(2,13) = 7.0
      YD(3,1) = 2.77808
      YD(3,2) = 1.75733
      YD(3,3) = 2.15446
      YD(3,4) = 1.23516
      YD(3,5) = 4.10837
      YD(3,6) = 0.78951
      YD(3,7) = 8.71836
      YD(3,8) = 3.74721
```

```
      YD(3,9) = 1.55366
      YD(3,10) = 25.0
      YD(3,11) = 0.27250
      YD(3,12) = 0.76882
      YD(3,13) = 8.0
      ACTC  (1,5) = 0.4
      ACTC  (2,5) = 0.4
      ACTC  (3,5) = 0.4
      ACTC  (1,11) = 0.5
      ACTC  (2,11) = 0.5
      ACTC  (3,11) = 0.5
      BAM(1) = 1.230
      BAM(2) = 1.157
      BAM(3) = 1.320
      UCIS(1) = 0.0
      UCIS(2) = 0.0
      UCIS(3) = 0.0
      DO 11 I = 1,3
      FLBD(I,1,1) = 0.311
      FLBD(I,1,2) = 0.346
      FLBD(I,2,1) = 0.307
      FLBD(I,2,2) = 0.320
      FLBD(I,3,1) = 0.276
      FLBD(I,3,2) = 0.284
      FLBD(I,4,1) = 0.098
      FLBD(I,4,2) = 0.158
      FLBD(I,5,1) = 0.650
      FLBD(I,5,2) = 0.245
      FLBD(I,6,1) = 0.098
      FLBD(I,6,2) = 0.158
      FLBD(I,7,1) =  0.242
      FLBD(I,7,2) =  0.202
      FLBD(I,8,1) =  0.144
      FLBD(I,8,2) =  0.231
      FLBD(I,9,1) = 0.654
      FLBD(I,9,2) =  0.691
      FLBD(I,10,1) = 0.218
      FLBD(I,10,2) = 0.293
      FLBD(I,11,1) = 0.164
      FLBD(I,11,2) = 0.106
      FLBD(I,12,1) = 0.287
      FLBD(I,12,2) = 0.232
      FLBD(I,13,1) = 0.010
      FLBD(I,13,2) = 0.020
11    CONTINUE

      DO 12 I = 1,3
      IBEXYR(I,1,1) = 1971
      IBEXYR(I,1,2) = 1974
      IBEXYR(I,1,3) = 1977
      IBEXYR(I,1,4) = 1979
      IBEXYR(I,1,5) = 1982
      IBEXYR(I,2,1) = 1971
      IBEXYR(I,2,2) = 1976
      IBEXYR(I,2,3) = 1978
      IBEXYR(I,2,4) = 1982
      IBEXYR(I,2,5) = 1999
      IBEXYR(I,3,1) = 1971
      IBEXYR(I,3,2) = 1976
      IBEXYR(I,3,3) = 1978
      IBEXYR(I,3,4) = 1982
```

```
      IBEXYR(I,3,5) = 1999                                              INPMFP
      IBEXYR(I,4,1) = 1971                                              INPMFP
      IBEXYR(I,4,2) = 1976                                              INPMFP
      IBEXYR(I,4,3) = 1981                                              INPMFP
      IBEXYR(I,4,4) = 1999                                              INPMFP
      IBEXYR(I,4,5) = 1999                                              INPMFP
      IBEXYR(I,5,1) = 1971                                              INPMFP
      IBEXYR(I,5,2) = 1976                                              INPMFP
      IBEXYR(I,5,3) = 1981                                              INPMFP
      IBEXYR(I,5,4) = 1999                                              INPMFP
      IBEXYR(I,5,5) = 1999                                              INPMFP
      IBEXYR(I,6,1) = 1971                                              INPMFP
      IBEXYR(I,6,2) = 1974                                              INPMFP
      IBEXYR(I,6,3) = 1978                                              INPMFP
      IBEXYR(I,6,4) = 1982                                              INPMFP
      IBEXYR(I,6,5) = 1999                                              INPMFP
      IBEXYR(I,7,1) = 1971                                              INPMFP
      IBEXYR(I,7,2) = 1974                                              INPMFP
      IBEXYR(I,7,3) = 1977                                              INPMFP
      IBEXYR(I,7,4) = 1980                                              INPMFP
      IBEXYR(I,7,5) = 1983                                              INPMFP
      IBEXYR(I,8,1) = 1971                                              INPMFP
      IBEXYR(I,8,2) = 1974                                              INPMFP
      IBEXYR(I,8,3) = 1977                                              INPMFP
      IBEXYR(I,8,4) = 1980                                              INPMFP
      IBEXYR(I,8,5) = 1983                                              INPMFP
      IBEXYR(I,9,1) = 1971                                              INPMFP
      IBEXYR(I,9,2) = 1974                                              INPMFP
      IBEXYR(I,9,3) = 1977                                              INPMFP
      IBEXYR(I,9,4) = 1980                                              INPMFP
      IBEXYR(I,9,5) = 1983                                              INPMFP
      IBEXYR(I,10,1) = 1971                                             INPMFP
      IBEXYR(I,10,2) = 1974                                             INPMFP
      IBEXYR(I,10,3) = 1977                                             INPMFP
      IBEXYR(I,10,4) = 1980                                             INPMFP
      IBEXYR(I,10,5) = 1983                                             INPMFP
      IBEXYR(I,11,1) = 1971                                             INPMFP
      IBEXYR(I,11,2) = 1974                                             INPMFP
      IBEXYR(I,11,3) = 1977                                             INPMFP
      IBEXYR(I,11,4) = 1980                                             INPMFP
      IBEXYR(I,11,5) = 1983                                             INPMFP
      IBEXYR(I,12,1) = 1971                                             INPMFP
      IBEXYR(I,12,2) = 1974                                             INPMFP
      IBEXYR(I,12,3) = 1977                                             INPMFP
      IBEXYR(I,12,4) = 1980                                             INPMFP
      IBEXYR(I,12,5) = 1983                                             INPMFP
      IBEXYR(I,13,1) = 1974                                             INPMFP
      IBEXYR(I,13,2) = 1977                                             INPMFP
      IBEXYR(I,13,3) = 1980                                             INPMFP
      IBEXYR(I,13,4) = 1983                                             INPMFP
      IBEXYR(I,13,5) = 1999                                             INPMFP
      BEXD(I,1) = 0.15                                                  INPMFP
      BEXD(I,2) = 0.07                                                  INPMFP
      BEXD(I,3) = 0.05                                                  INPMFP
      BEXD(I,4) = 0.03                                                  INPMFP
      BEXD(I,5) = 0.03                                                  INPMFP
      BEXD(I,6) = 0.03                                                  INPMFP
      BEXD(I,7) = 0.025                                                 INPMFP
      BEXD(I,8) = 0.02                                                  INPMFP
      BEXD(I,9) = 0.017                                                 INPMFP
      BEXD(I,10) = 0.015                                                INPMFP
```

```
      BEXD(I,11) = 0.013
      BEXD(I,12) = 0.01
      BEXD(I,13) = 0.01
      DO 12 J = 1,13
      GZSTM1(I,J) = 0.0
      PROFTY(I,J) = 0.0
      YLD(I,J) = YD(I,J)
      DO 9 L = 1,3
      FX(I,J,L) = FXD(I,J,L)
 9    PROFTY(I,J ) = PROFTY(I,J) + (PD(I,J)*YD(I,J) - FXD(I,J,L)*
     1              PXD(I,L))
      DO 12 K = 1,5
      AMP(I,J,K) = 0.0
      TSP(I,J,K) = 0.0
      TDP(I,J,K) = 100.0
      DGA(I,J,K) = 0.0
 12   CONTINUE
      DO 13 M = 1,5
      DO 13 J = 1,13
      DO 13 K = 1,5
      RGA1(M,J,K) = 0.0
      RGA2(M,J,K) = 0.0
      RGA3(M,J,K) = 0.0
 13   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SUBINV                                                 INPHFP   428
      COMMON /CONTR/  DT,DTP,DTY,FINEDT,IALT,IALTEX(3),IDT,IPCSD,       CONTR      2
     1                IDRDTH,IPRP(6),IPRPHD,IRUN,ISENS,ITIME,IYEAR,     CONTR      3
     2                JPER,NCOM,NCROP,NDTPOP,NTDPR2,NREGN,NRUN,NT,      CONTR      4
     3                NTIME,NYEARS,NYRPR2,T,YEAR,YEARAG,YEARO,NCOMAG    CONTR      5
      COMMON /VAIC/ FXDM1(3,13,3), FX(3,13,3),  FXD(3,13,3),PXD(3,3),   VAIC       2
     1              IBEXYR(3,13,5),PD(3,13),    YD(3,13),    ACTC(3,13),VAIC       3
     2              QZSTH1(3,13),  RAM(3),      UCIS(3),     BEXD(3,13),VAIC       4
     3              AMP(3,13,5),   FLBD(3,13,2),PITP1(3),    PITP2(3),  VAIC       5
     4              TSP(3,13,5),   PROFTY(3,13),PITP3(3),    PITP4(3),  VAIC       6
     5              TDP(3,13,5),   CSLP(3),     PIT1(3),     PIT2(3),   VAIC       7
     6              RGA1(5,13,5),  DROP(3),     PIT3(3),     PIT4(3),   VAIC       8
     7              RGA2(5,13,5),  UCSUL(3),    D1TP(3,4),   D2TP(3,4), VAIC       9
     8              RGA3(5,13,5),  RCP(3),      RDP(3),      RCU(3),    VAIC      10
     9              DGA(3,13,5),   RIU(3),      RTD(3),      RUD(3),    VAIC      11
     1              RINT(5,3,8),   STRGP(3,8),  DSC(3,8),    S(3,8),    VAIC      12
     2              DSUL(3),       ULIG(3),     TL(3,8),     GLIRD(3)   VAIC      13
      COMMON /PTSF/ PAVG(3,13),  A(3,13),     TA(3),       PX(3,3),     PTSF       2
     1              ASOR(13),    SZC(3,13),   RSP(3,13),   AGREV(3,13), PTSF       3
     2              PXDM1(3,3),  PDM1(3,13),  TLAND(3),    YZD(3,13),   PTSF       4
     3              ACTCM1(3,13),SCR(3,7),    APSC(3,8),   WAP(3,2),    PTSF       5
     4              SLDR(3,2),   STLAND,      STA,         SAGREV(3)    PTSF       6
      COMMON /VPRT/ TPLAND(3),   TULAND(3),   TCPA(3,8),   SFUCEY(3,13),VPRT       2
     1              TCPD(3,8),   QTZS(3,13),  QZS(3,13),   PIEYLD(3,13),VPRT       3
     2              QZ(3,13,5),  QTZ(3,13,5), TREV(3),     ACEYYY(3,13),VPRT       4
     3              TVC(3),      CC(3),       TPCOST(3),   YZDYYY(3,13),VPRT       5
     4              TNFIN(3),    TPP(3,13),   STPP(13),    SCEYYY(3,13),VPRT       6
     5              TFOK(3),     TGL(3),      TPVL1(3),    SYNLAN(3,13),VPRT       7
     6              TPVL2(3),    YLD(3,13),   AYLD(13),    AFX(13,3),   VPRT       8
     7              ATFLB(13),   AFLB(13,2),  TFLB(3,13),  FLB(3,13,2), VPRT       9
     8              STREV,       STVC,        SUCIS,       SCC,         VPRT      10
     9              STCOST,      STNFIN,      STFOK,       STGL,        VPRT      11
     1              STPVL1,      STPVL2,      SFXQ(3,13),  SSFXQ(3),    VPRT      12
     2              SSFX(3),     FOK(3),      GL(3),       PVL1(3),     VPRT      13
     3              PVL2(3)                                             VPRT      14
      DIMENSION RPI1T1(3),     RPI2T1(3),    RPI3T1(3),    RPI4T1(3),   INPHFP   433
     1          RCPTM1(3),     RDPTM1(3),    RCUTM1(3),    RIUTM1(3),   INPHFP   434
     2          RTDTM1(3),     RUDTM1(3),    WQ(5),        PT21(3),     INPHFP   435
     3          PT31(3),       PT32(3),      PT41(3),      PT42(3),     INPHFP   436
     4          TR(3),         UCSLP(3),     UDRDP(3),     PLR1(3),     INPHFP   437
     5          PLR2(3),       PLR3(3),      PLR4(3),      PLR5(3),     INPHFP   438
     6          PLR6(3),       PLR7(3),      PLR8(3),      PLR9(3),     INPHFP   439
     7          SDTYR(3),      SDUYR(3),     WPTLD(3),     WPULD(3),    INPHFP   440
     8          CRPI4(3),      E(3,8),       B(3,8),       DI(3,8),     INPHFP   441
     9          VALCT(5,8),    KCOST(3,8),   DEL(8),       DELDP(8),    INPHFP   442
     1          KDEL(8),       UULIG(3),     PLRP(8,8),    VALA(11),    INPHFP   443
     2          VALB(2),       APS1(3,8),    APS2(3,8),    RATDR(3,8),  INPHFP   444
     3          DELPA(8),      DELPP(8)                                 INPHFP   445
      DATA WQ/ 0.30, 0.35, 0.45, 0.60, 0.80/                            INPHFP   446
      DATA DI /                                                         INPHFP   447
     1      2.5, 4.5, 4.0,                                              INPHFP   448
     2     15.0,32.0, 17.0,                                             INPHFP   449
     3    10.0, 22.0, 3.5,                                              INPHFP   450
     4     13.0,27.0, 4.8,                                              INPHFP   451
     5     30.0,60.0, 10.0,                                             INPHFP   452
     6      7.0,15.0, 2.5,                                              INPHFP   453
     7     16.0,35.0, 12.0,                                             INPHFP   454
     8     18.0,40.0, 15.0/                                             INPHFP   455
      DATA SMALL/ 0.0/                                                  INPHFP   456
      DATA PT21,PT31,PT32,PT41,PT42/                                    INPHFP   457
     1     0.55, 0.55, 0.55,                                            INPHFP   458
```

```
2         0.3,  0.3,  0.3,
3         0.7,  0.7,  0.7,
4         0.15, 0.15, 0.15,
5         0.3,  0.3,  0.3/
      DATA TR / 2.8,  5.5,  1.5 /
      DATA B /
1         323.495,  600.000,      0.0,
2         498.800, 1080.400,    541.300,
3        907.120,  1440.720,  820.160,
4       1149.540,  1825.740,  416.210,
5         754.500, 1623.600,   285.300,
6         188.700,  406.200,    71.400,
7         303.500,  661.200,   233.000,
8         587.500, 1272.500,   500.000/
      DATA PADSC1,PADSC2,PADSC3,PADSC4,PADSC5,PLRP /
1         0.01, 0.003, 0.007,0.005, 0.003, 24*0.0/
      DATA WTR1,WTR2,WTR3,WTR4,WTR5,WTR6,WTR7,WTR8,WTR979*1.0/
      DATA VALCT/
1         500.0, 505.0, 512.5, 525.0, 550.0,
2         120.0, 121.2, 123.0, 126.0, 132.0,
3         500.0, 505.0, 512.5, 525.0, 550.0,
4         350.0, 353.5, 358.5, 368.0, 385.0,
5         100.0, 101.0, 102.5, 105.0, 110.0,
6         100.0, 101.0, 102.5, 105.0, 110.0,
7          70.0,  70.7,  71.7,  73.5,  77.0,
8         120.0, 121.2, 123.0, 126.0, 132.0/
      DATA KCOST/24*4/
      DATA KDEL/ 3, 5, 3, 5*5/
      DATA DELDP/ 3.0, 2.0, 2.5, 1.5, 1.5, 1.0, 1.0, 1.5/
      DATA DELPP/ 3.0, 2.0, 2.5, 1.5, 1.5, 1.0, 1.0, 1.5/
      DATA VALA/20.0, 11.0, 7.4, 5.0, 3.5, 2.5, 1.8, 1.5, 1.25, 1.1,1.0/
      DATA VALB/1.0, 0.6/
      DATA DIFA,KA,SHALB,KB,PCPA,APPA, DIFB/
1         0.1, 10, 1.0, 1, 0.07, 0.015, 1.0/
      DT = 0.25
      DO 1000 KK = 1,4
      DO 800 I = 1,3
      TPLAND(I) = PIT1(I) + PIT2(I) + PIT3(I) + PIT4(I)
      RPI1T1(I) = PITP1(I)
      RPI2T1(I) = PITP2(I)
      RPI3T1(I) = PITP3(I)
      RPI4T1(I) = PITP4(I)
      PITP1(I) = PIT1(I)/TPLAND(I)
      PITP2(I) = PIT2(I)/TPLAND(I)
      PITP3(I) = PIT3(I)/TPLAND(I)
      PITP4(I) = PIT4(I)/TPLAND(I)
      UCSLP(I) = TPLAND(I) - CSLP(I)
      UDRDP(I) = TPLAND(I) - DRDP(I)
      TULAND(I) = CSUL(I) + UCSUL(I)
      TLAND(I) = TPLAND(I) + TULAND(I)
      UULIG(I) = TULAND(I) - ULIG(I)
      PLR1(I) = PIT1(I)/TLAND(I)
      PLR2(I) = PIT2(I)/TLAND(I)
      PLR3(I) = PIT3(I)/TLAND(I)
      PLR4(I) = PIT4(I)/TLAND(I)
      PLR5(I) = CSLP(I)/TLAND(I)
      PLR6(I) = DRDP(I)/TLAND(I)
      PLR7(I) = CSUL(I)/TLAND(I)
      PLR8(I) = UCSUL(I)/TLAND(I)
      PLR9(I) = ULIG(I)/TLAND(I)
      IF (AMOD(T,1.0) .NE. 0.0) GO TO 19
```

```
      SDTYR(I) = DSC(I,1)                                               INPHFP
      SDUYR(I) = DSC(I,2)                                               INPHFP
      WPTLD(I) = WG(1)*DSC(I,1)                                         INPHFP
      WPULD(I) = WG(1)*DSC(I,2)                                         INPHFP
      DO 20 L = 1,4                                                     INPHFP
      WPTLD(I) = WPTLD(I) + WG(L+1)*D1TP(I,L)                           INPHFP
      WPULD(I) = WPULD(I) + WG(L+1)*D2TP(I,L)                           INPHFP
      SDTYR(I) = SDTYR(I) + D1TP(I,L)                                   INPHFP
   20 SDUYR(I) = SDUYR(I) + D2TP(I,L)                                   INPHFP
      IF (SDTYR(I) .NE. 0.0) GO TO 23                                   INPHFP
      WAP(I,1) = 0.0                                                    INPHFP
      GO TO 24                                                          INPHFP
   23 WAP(I,1) = WPTLD(I)/SDTYR(I)                                      INPHFP
   24 WAP(I,2) = WPULD(I)/SDUYR(I)                                      INPHFP
   19 CONTINUE                                                          INPHFP
      RCPTM1(I) = RCP(I)                                                INPHFP
      RDPTM1(I) = RDP(I)                                                INPHFP
      RCUTM1(I) = RCU(I)                                                INPHFP
      RIUTM1(I) = RIU(I)                                                INPHFP
      RTDTM1(I) = RTD(I)                                                INPHFP
      RUDTM1(I) = RUD(I)                                                INPHFP
      RCP(I) = CSLP(I)/TPLAND(I)                                        INPHFP
      RDP(I) = DRDP(I)/TPLAND(I)                                        INPHFP
      RCU(I) = CSUL(I)/TULAND(I)                                        INPHFP
      RIU(I) = ULIG(I)/TULAND(I)                                        INPHFP
      RTD(I) = SDTYR(I)/TPLAND(I)                                       INPHFP
      RUD(I) = SDUYR(I)/TULAND(I)                                       INPHFP
      SCR(I,1) = (PITP1(I) - RPI1T1(I))/RPI1T1(I)                       INPHFP
      SCR(I,2) = (PITP2(I) - RPI2T1(I))/RPI2T1(I)                       INPHFP
      SCR(I,3) = (PITP3(I) - RPI3T1(I))/RPI3T1(I)                       INPHFP
      CRPI4(I) = PITP4(I) - RPI4T1(I)                                   INPHFP
      SCR(I,4) = (RCP(I) - RCPTM1(I))/RCPTM1(I)                         INPHFP
      SCR(I,5) = (RDP(I) - RDPTM1(I))/RDPTM1(I)                         INPHFP
      SCR(I,6) = RCU(I) - RCUTM1(I)                                     INPHFP
      SCR(I,7) = RIU(I) - RIUTM1(I)                                     INPHFP
      IF (AMOD(T,1.0) .NE. 0.0) GO TO 21                                INPHFP
      SLDR(I,1) = RTD(I) - RTDTM1(I)                                    INPHFP
      SLDR(I,2) = RUD(I) - RUDTM1(I)                                    INPHFP
   21 CONTINUE                                                          INPHFP
      DO 30 K = 1,8                                                     INPHFP
      APS1(I,K) = TABLIE(VALCT(1,K),SMALL,DI(I,K),KCOST(I,K),S(I,K))    INPHFP
      APS2(I,K) = TABLIF(VALCT(1,K),SMALL,DI(I,K),KCOST(I,K),TL(I,K))   INPHFP
      APSC(I,K) = (APS1(I,K) + APS2(I,K))/2.0*EXP(APRA*T)               INPHFP
      IF (STRGP(I,K).EQ.0.0) GO TO 25                                   INPHFP
      TCPD(I,K) = APSC(I,K)/DELPP(K)*STRGP(I,K)                         INPHFP
      TCPA(I,K) = TCPD(I,K)                                             INPHFP
      RATDB(I,K) = TCPA(I,K)/TCPD(I,K)                                  INPHFP
      GO TO 26                                                          INPHFP
   25 TCPD(I,K) = 0.0                                                   INPHFP
      TCPA(I,K) = 0.0                                                   INPHFP
      RATDB(I,K) = 1.0                                                  INPHFP
   26 IF (RATDB(I,K).LT.1.0) GO TO 31                                   INPHFP
      IF (RATDB(I,K).GE.1.0) GO TO 32                                   INPHFP
   31 DELPA(K) = TABLIE (VALA,SMALL,DIFA,KA,RATDB(I,K))                 INPHFP
      GO TO 33                                                          INPHFP
   32 DELPA(K) = TABLIE (VALB,SHALB,DIFB,KB,RATDB(I,K))                 INPHFP
   33 DEL(K) = DELPA(K)*DELPP(K)                                        INPHFP
      E(I,K) = B(I,K)/APSC(I,K)                                         INPHFP
      S(I,K) = S(I,K) + DT*E(I,K)                                       INPHFP
   30 TL(I,K) = TL(I,K) + DT*USC(I,K)                                   INPHFP
      PIT1(I) = PIT1(I) + DT*(DSC(I,3)*(1.0 - PADSCI) + DSC(I,1) *      INPHFP
```

```
     1            PADSC3*PITP1(I)*DSC(I,5) - WTR1*PLR1(I)*TR(I))
      PIT2(I) = PIT2(I) + DT*(DSC(I,4)*(1.0 - PADSC2) - PT21(I)*DSC(I,3)
     1          - PADSC3*PITP2(I)*DSC(I,5) - WTR2*PLR2(I)*TR(I))
      PIT3(I) = PIT3(I) + DT*(PT31(I)*DSC(I,3) + PT32(I)*DSC(I,4) +
     1            PADSC3*PITP3(I)*DSC(I,5) + WTR3*PLR3(I)*TR(I))
      PIT4(I) = PIT4(I) + DT*(PT41(I)*DSC(I,3) + PT42(I)*DSC(I,4) +
     1            PADSC3*PITP4(I)*DSC(I,5) + WTR4*PLR4(I)*TR(I))
      CSLP(I) = CSLP(I) + DT*(DSC(I,5)*(1.0 - PADSC3) + DSC(I,3)*(1.0 -
     1            PADSC1)*(1.0 - RCP(I)) + DSC(I,1) - WTR5*PLR5(I)*TR(I))
      DRDP(I) = DRDP(I) + DT*(DSC(I,6) + DSC(I,3)*(1.0 - RDP(I))*(1.0 -
     1            PADSC1) + DSC(I,1) - WTR6*PLR6(I)*TR(I))
      CSUL(I) = CSUL(I) + DT*(DSC(I,7)*(1.0 - PADSC4) - WTR7*
     1            PLR7(I)*TR(I))
      UCSUL(I) = UCSUL(I) - DT*(DSC(I,7) - DSC(I,2) + WTR8*
     1            PLR8(I)*TR(I))
      ULIG(I) = ULIG(I) + DT*(DSC(I,8)*(1.0 - PADSC5) - WTR9*
     1            PLR9(I)*TR(I))
      IF (AMOD(T,1.0) .NE. 0.0) GO TO 45
      DO 40 L = 1,3
      D1TP(I,5-L) = D1TP(I,4-L)
40    D2TP(I,5-L) = D2TP(I,4-L)
      D1TP(I,1) = DSC(I,1)
      D2TP(I,1) = DSC(I,2)
45    CONTINUE
      DO 50 K = 1,8
50    CALL DELLVF(E(I,K),DSC(I,K),RINT(1,I,K),STRGP(I,K),PLRP(I,K),
     1              DEL(K),DELDP(K),DT,KDEL(K))
800   CONTINUE
      T = T + DT
1000  CONTINUE
      DT = 1.0
      T = T - 1.0
      RETURN
      END
```

```
      SUBROUTINE TEMP                                                     TEMP
      COMMON /CONTR/  DT,DTP,DTY,FINEDT,IALT,IALTEX(3),IDT,IPCSD,         CONTR
     1                IDROTH,IPBP(6),IPRPRD,IRUN,ISENS,ITIME,IYEAR,       CONTR
     2                JPER,NCUM,NCROP,NDTPOP,NTDPR2,NRBGN,NRUN,NT,        CONTR
     3                NTIME,NYEARS,NYRPR2,T,YEAR,YEARAG,YEARO,NCQMAG      CONTR
      COMMON /VAIC/ FXDM1(3,13,5), FX(3,13,3),  FXD(3,13,3),PXD(3,3),     VAIC
     1              IBEXYR(3,13,5),RD(3,13),    YD(3,13),   ACTC(3,13),   VAIC
     2              QESTM1(3,13),  RAM(3),      UCIS(3),    BEXD(3,13),   VAIC
     3              AMP(3,13,5),   PLBD(3,13,2),PITP1(3),   PITP2(3),     VAIC
     4              TSP(3,13,5),   PROFTY(3,13),PITP3(3),   PITP4(3),     VAIC
     5              TDP(3,13,5),   CSLP(3),     PIT1(3),    PIT2(3),      VAIC
     6              RGA1(5,13,5),  DRDP(3),     PIT3(3),    PIT4(3),      VAIC
     7              RGA2(5,13,5),  UCSUL(3),    D1TP(3,4),  D2TP(3,4),    VAIC
     8              RGA3(5,13,5),  RCP(3),      RDP(3),     RCU(3),       VAIC
     9              DGA(3,13,5),   RIU(3),      RTD(8),     RUD(3),       VAIC
     1              RINT(5,3,8),   STRGP(3,8),  DSC(3,8),   S(3,8),       VAIC
     2              QSUL(3),       ULIG(3),     TL(3,8),    GLIRD(3)      VAIC
      COMMON /PTSF/ PAVG(3,13),  A(3,13),     TA(3),       PX(3,3),       PTSF
     1              ASOR(13),    SZC(3,13),   RSP(3,13),   AGREV(3,13),   PTSF
     2              PXDM1(3,3),  PDM1(3,13),  TLAND(7),    YZD(3,13),     PTSF
     3              ACTCM1(3,13),SCR(3,7),    APSC(3,8),   WAP(3,2),      PTSF
     4              SLDR(3,2),   STLAND,      SVA,         SAGREV(3)      PTSF
      COMMON /VPRT/ TPLAND(3),  TULAND(3),  TCPA(3,8),  SFUCEY(3,13),     VPRT
     1              TCPD(3,8),  GTZS(3,13), QZS(3,13),  PIEYLD(3,13),     VPRT
     2              QZ(3,13,5), GTZ(3,13,5),TREV(3),    ACEYYY(3,13),     VPRT
     3              TVC(3),     CC(3),      TPCOST(3),  YZDYYY(3,13),     VPRT
     4              TNFIN(3),   TPP(3,13),  STPP(13),   SCEYYY(3,13),     VPRT
     5              TFOK(3),    TGL(3),     TPVL1(3),   SYNLAN(3,13),     VPRT
     6              TPVL2(3),   YLD(3,13),  AYLD(13),   AFX(13,3),        VPRT
     7              ATFLB(13),  AFLB(13,2), TFLB(3,13), FLB(3,13,2),      VPRT
     8              STREV,      STVC,       SUCIS,      SOC,              VPRT
     9              STCOST,     STNFIN,     STFOK,      STGL,             VPRT
     1              STPVL1,     STPVL2,     SFXQ(3,13), SSFXQ(3),         VPRT
     2              SSFX(3),    FOK(3),     QL(3),      PVL1(3),          VPRT
     3              PVL2(3)                                               VPRT
      DIMENSION VCOST(3,13), VALP(3,4,13),VLAR(4),     VALA(3,4,13),      TEMP
     1          PXP(3,3),    PXBR(3,3),   VLPR(4),     VAAC1(4),          TEMP
     2          VAAC2(4),    SPROFY(3)                                    TEMP
      DATA VAAC1,VAAC2/ 0.4,0.45,0.5,0.55, 0.5,0.55,0.6,0.65/             TEMP
      DATA VALP/   3*75.,      9*115.,                                    TEMP
     1             3*47.,      3*72.,      3*58.,     3*65.,              TEMP
     2             3*24.,      9*52.7,                                    TEMP
     3             3*40.,      3*55.,      3*62.,     3*65.,              TEMP
     4             3*55.6,     3*50.,      3*56.7,    3*63.5,             TEMP
     5             3*100.,     9*130.,                                    TEMP
     6             3*48.5,     3*44.5,     3*51.2,    3*60.,              TEMP
     7             3*53.,      3*43.,      3*44.,     3*47.5,             TEMP
     8            12*205.,                                                TEMP
     9             3*10.,      3*13.,      3*15.,     3*17.,              TEMP
     1            12*461.,                                                TEMP
     2            12*159.,                                                TEMP
     3             3*5.,       3*6.5,      3*7.5,     3*8.5/              TEMP
      DATA VALA/ 350., 748., 132., 352., 750., 132., 356., 759., 134.,    TEMP
     1      360., 767., 135.,       135., 719.,  95., 138., 738.,  97.,   TEMP
     2      146., 776., 102., 151., 808., 107.,        34., 107.,  29.,   TEMP
     3       35., 108.,  29.,  35., 110.,  29.,  35., 109.,  29.,         TEMP
     4       13.,  67.,  64.,  10.,  51.,  49.,   7.,  34.,  33.,   3.,   TEMP
     5       17.,  16.,        18.,  33.,   9.,  25.,  46.,  12.,  31.,   TEMP
     6       59.,  15.,  37.,  71.,  18.,       112., 178.,  88., 116.,   TEMP
     7      161.,  88., 121., 191.,  95., 126., 201.,  99.,        71.,   TEMP
     8      122.,  33.,  95., 168.,  44., 103., 176.,  48., 110., 188.,   TEMP
```

```
          51.,        25., 125.,  43.,  32., 160.,  55.,  361, 178.,    TEMP
     1    61.,  39., 198.,  68.,         6.,  22.,  12.,   7.,  27.,    TEMP
     2    15.,   7.,  28.,  15.,   8.,  31.,  17.,          61,  15.,    TEMP
     3     4.,   8.,  24.,   7.,  11.,  30.,   9.,  15.,  35.,  10.,    TEMP
     4          15.,  61.,  23.,  17.,  67.,  26.,  19.,  76.,  29.,    TEMP
     5    21.,  87.,  33.,        13.,  58.,  181,  12.,  561,  17.,    TEMP
     6    13.,  58.,  18.,  15.,  60.,  19.,        13.,  58.,  18.,    TEMP
     7    12.,  56.,  17.,  15.,  58.,  18.,  131,  80.,  191/          TEMP
      DATA SHALL,DIFF,KTP/1970.,5.,3/                                   TEMP
      DATA PXP,PXBR/ 9*1.0, 9*0.15 /                                    TEMP
C                                                                       TEMP
C  PRODUCER PRICE,AREA PLANTED,AND TOTAL LAND                           TEMP
C                                                                       TEMP
      DO 51 I = 1,3                                                     TEMP
      DO 51 J = 1,13                                                    TEMP
      DO 50 K = 1,4                                                     TEMP
      VLPR(K) = VALP(I,K,J)                                             TEMP
 50   VLAR(K) = VALA(I,K,J)                                             TEMP
      PAVG(I,J) = TABLIE (VLPR,SHALL,DIFF,KTP,YEAR                      TEMP
 51   A(I,J) = TABLIE (VLAR,SHALL,DIFF,KTP,YEAR)                        TEMP
      DO 54 I = 1,3                                                     TEMP
 54   TA(I) = 0.0                                                       TEMP
      DO 55 I = 1,3                                                     TEMP
      DO 55 J = 1,13                                                    TEMP
 55   TA(I) = TA(I) + A(I,J)                                            TEMP
      STA = 0.0                                                         TEMP
      DO 56 I = 1,3                                                     TEMP
 56   STA = STA + TA(I)                                                 TEMP
      DO 57 I = 1,3                                                     TEMP
      ACTCM1(I,5) = ACTC(I,5)                                           TEMP
      ACTC(I,5) = TABLIE (VAAC1,SHALL,DIFF,KTP,YEAR)                    TEMP
      ACTCM1(I,11) = ACTC(I,11)                                         TEMP
 57   ACTC(I,11) = TABLIE (VAAC2,SHALL,DIFF,KTP,YEAR                    TEMP
C  FACTOR PRICE INDEX                                                   TEMP
      DO 58 L=1,3                                                       TEMP
      R2=RANF(1)                                                        TEMP
      DO 58 I=1,3                                                       TEMP
58    PX(I,L)=PXP(I,L)+(R2*PXBR(I,L)-0.5*PXBR(I,L))                     TEMP
C  SUM OF LAND                                                          TEMP
      DO 65 J = 1,13                                                    TEMP
 65   ASOR(J) = 0.0                                                     TEMP
      STLAND = 0.0                                                      TEMP
      DO 66 I = 1,3                                                     TEMP
      STLAND = STLAND + TLAND(I)                                        TEMP
      DO 66 J = 1,13                                                    TEMP
 66   ASOR(J) = ASOR(J) + A(I,J)                                        TEMP
C  SIZE OF CROP AND REGIONAL SPECIALIZATION                             TEMP
      DO 67 I = 1,3                                                     TEMP
      DO 67 J = 1,13                                                    TEMP
      SZC(I,J) = A(I,J)/TLAND(I)                                        TEMP
 67.  RSP(I,J) = SZC(I,J)/(ASOR(J)/STLAND)                              TEMP
C  PROFITABILITY OF CROP                                                TEMP
      DO 68 I = 1,3                                                     TEMP
      DO 68 J = 1,13                                                    TEMP
 68   VCOST(I,J) = 0.0                                                  TEMP
      DO 69 I = 1,3                                                     TEMP
      DO 69 J = 1,13                                                    TEMP
      DO 69 L = 1,3                                                     TEMP
 69   VCOST(I,J) = VCOST(I,J) + PXD(I,L)*FXD(I,J,L)                     TEMP
      DO 70 I = 1,3                                                     TEMP
      DO 70 J = 1,13                                                    TEMP
```

```
      AGREV(I,J) = PD(I,J)*YD(I,J)
 70   PROFTY(I,J) = AGREV(I,J) - VCOST(I,J)
      DO 71 I = 1,3
      SAGREV(I) = 0.0
 71   SPROFY(I) = 0.0
      DO 72 I = 1,3
      DO 72 J = 1,13
      SAGREV(I) = SAGREV(I) + AGREV(I,J)
 72   SPROFY(I) = SPROFY(I) + PROFTY(I,J)
C  DISTRIBUTED LAG PRICES
      DO 80 I = 1,3
      DO 80 L = 1,3
      PXDM1(I,L) = PXD(I,L)
 80   PXD(I,L) = PXD(I,L) + DT*(PX(I,L) - PXD(I,L))/3.0
      DO 81 I = 1,3
      DO 81 J = 1,13
      PDM1(I,J) = PD(I,J)
 81   PD(I,J) = PD(I,J) + DT*(PAVG(I,J) - PD(I,J))/3.0
      RETURN
      END
```

```
      SUBROUTINE SOCDIF                                                 SOCDIF   2
      COMMON /CONTR/  DT,DTP,DTY,FINEDT,IALT,IALTEX(3),IDT,IPCBD,       CONTR    2
     1                IDROTH,IPRP(6),IPRPRD,IRUN,ISENS,ITIME,IYEAR,     CONTR    3
     2                JPER,NCOM,NCROP,NDTPOP,NTDPR2,NREGN,NRUN,NT,      CONTR    4
     3                NTIME,NYEARS,NYRPR2,T,YEAR,YEARAG,YEARO,NCOMAG    CONTR    5
      COMMON /VAIC/ FXDM1(3,13,3), FX(3,13,3),  FXD(3,13,3),PXD(3,3),   VAIC     2
     1              IDEXYR(3,13,5),PD(3,13),    YD(3,13),    ACTC(3,13), VAIC    3
     2              GZSTH1(3,13),  RAM(3),      UCIS(3),     BEXD(3,13), VAIC    4
     3              AHP(3,13,5),   FLBD(3,13,2),PITP1(3),    PITP2(3),   VAIC    5
     4              TSP(3,13,5),   PROFTY(3,13),PITP3(3),    PITP4(3),   VAIC    6
     5              TDP(3,13,5),   CSLP(3),     PIT1(3),     PIT2(3),    VAIC    7
     6              RGA1(5,13,5),  DRDP(3),     PIT3(3),     PIT4(3),    VAIC    8
     7              RGA2(5,13,5),  UCSUL(3),    D1TP(3,4),   D2TP(3,4),  VAIC    9
     8              RGA3(5,13,5),  RCP(3),      RDP(3),      RCU(3),     VAIC   10
     9              DGA(3,13,5),   RIU(3),      RTD(3),      RUD(3),     VAIC   11
     1              RINT(5,3,8),   STRGP(3,8),  DSC(3,8),    S(3,8),     VAIC   12
     2              CSUL(3),       ULIG(3),     TL(3,8),     GLIRD(3)    VAIC   13
      COMMON /PTSF/ PAVG(3,13),  A(3,13),      TA(3),        PX(3,3),    PTSF    2
     1              ASOR(13),    SZC(3,13),    RSP(3,13),    AGREV(3,13), PTSF   3
     2              PXDM1(3,3),  PDM1(3,13),   TLAND(3),     YZD(3,13),  PTSF    4
     3              ACTCM1(3,13),SCR(3,7),     APSC(3,8),    WAP(3,2),   PTSF    5
     4              SLDR(3,2),   STLAND,       STA,          SAGREV(3)   PTSF    6
      COMMON /VPRT/ TPLAND(3),  TULAND(3),  TCPA(3,8),  SFUCEY(3,13),   VPRT     2
     1              TCPD(3,8),  GTZS(3,13), GZS(3,13),  PIEYLD(3,13),   VPRT     3
     2              GZ(3,13,5), GTZ(3,13,5),TREV(3),    ACEYYY(3,13),   VPRT     4
     3              TVC(3),     CC(3),      TPCOST(3),  YZDYYY(3,13),   VPRT     5
     4              TNFIN(3),   TPP(3,13),  STPP(13),   SCEYYY(3,13),   VPRT     6
     5              TFOK(3),    TGL(3),     TPVL1(3),   SYNLAN(3,13),   VPRT     7
     6              TPVL2(3),   YLD(3,13),  AYLD(13),   AFX(13,3),      VPRT     8
     7              ATFLB(13),  AFLB(13,2), TFLB(3,13), FLB(3,13,2),    VPRY     9
     8              STREV,      STVC,       SUCIS,      SCC,            VPRT    10
     9              STCOST,     STNFIN,     STFOK,      STGL,           VPRT    11
     1              STPVL1,     STPVL2,     SFXO(3,13),  SSFXO(3),      VPRT    12
     2              SSFX(3),    FOK(3),     GL(3),       PVL1(3),       VPRT    13
     3              PVL2(3)                                             VPRT    14
      DIMENSION BEX(3),        BEXIJ(3,13), SSCORE(3),   SCORE(3,13),   SOCDIF   7
     1          PSCORE(3,13),PROFCH(3,13),GA(3,13,5),   EGEDF(3,13),    SOCDIF   8
     2          PFEDF(3,13), PCEDF(3,13), CSEDF(3,13),  RSEDF(3,13),    SOCDIF   9
     3          VADF1(6),    VABF2(6),    VADF3(5),     ROEDF(3,13,5),  SOCDIF  10
     4          VADF4(7),    VADF5(5),    VADF6(5),     VADF7(6),       SOCDIF  11
     5          DDF(3,13,5), AEB(3,13,5), AHT(3,13,5),  RYDIFF(3,13,5), SOCDIF  12
     6          EDF(3,13,5), HRF(3,13,5), DF(3,13,5),   IDTGA(3,13,5),  SOCDIF  13
     7          AR(3,13,5),  YZTM1(3,13), YZ(3,13),     PROFM1(3,13)    SOCDIF  14
      DIMENSION VADF8(6),RYINCR(3,13,5),RYDISS(3,13,5)                  SOCDIF  15
      DATA RYINCR/ 3*0.2,   24*0.1,   3*0.2,   9*0.1,                   SOCDIF  16
     1             3*0.1,   9*0.3,    6*0.2,   3*0.1,     3*0.2,        SOCDIF  17
     2               3*0.1, 3*0.3,    6*0.1,   3*0.3,                   SOCDIF  18
     3             3*0.3,   3*0.1,    3*0.2,   3*0.3,     3*0.2,        SOCDIF  19
     4               9*0.3, 3*0.1,    3*0.3,   6*0.1,     3*0.2,        SOCDIF  20
     5             3*0.1,   6*0.2,    6*0.0,   3*0.2,     6*0.3,        SOCDIF  21
     6               3*0.1, 3*0.3,    6*0.1,   3*0.3,                   SOCDIF  22
     7             3*0.3,   15*0.0,   6*0.2,   3*0.1,     3*0.3,        SOCDIF  23
     8               6*0.1, 3*0.0/                                      SOCDIF  24
      DATA RYDISS/ 195*0.5 /                                            SOCDIF  25
      DATA VADF1/ 0.75, 1.06, 1.25, 1.40, 1.48, 1.50/                   SOCDIF  26
      DATA VADF2/ 0.50, 0.80, 1.02, 1.17, 1.22, 1.25/                   SOCDIF  27
      DATA VADF3/ 0.75, 0.97, 1.13, 1.22, 1.25/                         SOCDIF  28
      DATA VADF4/ 0.50, 0.75, 0.95, 1.10, 1.20, 1.23, 1.25/             SOCDIF  29
      DATA VADF5/ 0.75, 0.97, 1.13, 1.22, 1.25/                         SOCDIF  30
      DATA VADF6/ 1.00, 1.50, 1.75, 1.90, 2.00/                         SOCDIF  31
      DATA VADF7/  0.03, 0.03, 0.035, 0.042, 0.051, 0.063/              SOCDIF  32
```

```
      DATA VADF8/ 0.003, 0.007, 0.01, 0.012, 0.0138, 0.015/
      DATA SHALL,SHACH,BEXA,BEXB,KGA/ 0.0, -0.2, 0.5, 0.5, 5/
      DATA DIFDF1,DIFDF2,DIFDF3,DIFDF4,DIFDF5,DIFDF6,DIFDF7/
     1     0.04, 100.0, 0.1, 0.1, 0.5, 0.05, 20.0/
      DATA KDF1,KDF2,KDF3,KDF4,KDF5,KDF6,KDF7/ 5,5,4,6,4,4,5/
      DATA SCOR1,SCOR2,SCOR3,SCOR4/4*1.0/
      DATA AEEA,AHTA,DFC,DGAM,RRFM,RRFA/
     1           0.015, 0.3, 0.8, 11.0, 0.1, 0.05/
      DATA PSCORE/ 39*1.0/
      DATA GBEXI,GGBEX/ 531.113, 0.03/
      RYEAR = YEAR + 0.000001
      GBEX = ( 1.0 + GGBEX*T)*GBEXI
      DO 900 I = 1,3
      BEX(I) = (BEXA*TA(I)/STA + BEXB*TLAND(I)/STLAND)*GBEX
      SSCORE(I) = 0.0
      DO 800 J = 1,13
      PROFM1(I,J) = PROFTY(I,J)
      PROFCH(I,J) = (PROFTY(I,J) - PROFM1(I,J))/PROFM1(I,J)
      BEEDF(I,J) = TABLIE(VADF1,SHALL,DIFDF1,KDF1,BEXD(I,J))
      PFEDF(I,J) = TABLIE(VADF2,SHALL,DIFDF2,KDF2,PROFTY(I,J))
      PCEDF(I,J) = TABLIE(VADF3,SHACH,DIFDF3,KDF3,PROFCH(I,J))
      BSEDF(I,J) = TABLIE(VADF4,SHALL,DIFDF4,KDF4,SZC(I,J))
      RSEDF(I,J) = TABLIE(VADF5,SHALL,DIFDF5,KDF5,RSP(I,J))
      SCORE(I,J) = SCOR1*PFEDF(I,J) + SCOR2*PCEDF(I,J) +
     1             SCOR3*CSEDF(I,J) + SCOR4*RSEDF(I,J) + PSCORE(I,J)
      SSCORE(I) = SSCORE(I) + SCORE(I,J)
      BEXIJ(I,J) = (SCORE(I,J)/SSCORE(I))*(BEX(I)/TA(I))
      GZS(I,J) = 0.0
      GTZS(I,J) = 0.0
      DO 700 K = 1,5
      IF (IBEXYR(I,J,K).EQ.0) GO TO 700
      IF (KYEAR .LT. (IBEXYR(I,J,K) - 1.0)) GO TO 700
      RYDIFF(I,J,K) = RYINCR(I,J,K)*RYDISS(I,J,K)
      ROEDF(I,J,K) = TABLIE(VADF6,SHALL,DIFDF6,KDF6,RYDIFF(I,J,K))
      DDF(I,J,K) = ROEDF(I,J,K) + ROEDF(I,J,K)*(BEEDF(I,J)*(PFEDF(I,J)
     1             + PCEDF(I,J) + CSEDF(I,J) + RSEDF(I,J)))
      TDP(I,J,K) = 100.0 - AMP(I,J,K) - TSP(I,J,K)
      AEE(I,J,K) = AEEA*DDF(I,J,K)
      AMT(I,J,K) = AHTA*DDF(I,J,K)
      EDF(I,J,K) = AEE(I,J,K)*TDP(I,J,K) + AMT(I,J,K)*AMP(I,J,K) +
     1             DFC*AMT(I,J,K)*TSP(I,J,K)
      IF (DGA(I,J,K).NE.0.0) GO TO 50
      DGA(I,J,K) = AMAX1(1.0,(DGAM - DDF(I,J,K)))
      IDTGA(I,J,K) = 2.0*DT*KGA/DGA(I,J,K) + 1.0
50    RRF(I,J,K) = AMAX1(0.0,(RRFM - RRFA*DDF(I,J,K)))
      EDF(I,J,K) = AMIN1(EDF(I,J,K),TDP(I,J,K))
      IF ((AMP(I,J,K) + TSP(I,J,K)).LT.80.0) GO TO 51
      EDF(I,J,K) = TDP(I,J,K)
      RRF(I,J,K) = 0.0
51    GTZ(I,J,K) = (AMP(I,J,K) + TSP(I,J,K))*RYDIFF(I,J,K)
      GTZS(I,J) = GTZS(I,J) + GTZ(I,J,K)
      DF(I,J,K) = TABLIE(VADF7,SHALL,DIFDF7,KDF7,AMP(I,J,K))
      GZ(I,J,K) = (1.0 - DF(I,J,K))*RYDIFF(I,J,K)*(AMP(I,J,K) + DFC*
     1             TSP(I,J,K))
      GZS(I,J) = GZS(I,J) + GZ(I,J,K)
      IF (I.EQ.1) GO TO 60
      IF (I.EQ.2) GO TO 70
      IF (I.EQ.3) GO TO 80
60    CALL DELDD (EDF(I,J,K),GA(I,J,K),RGA1(1,J,K),DGA(I,J,K),IDTGA
     1            (I,J,K),DT,KGA,AR(I,J,K))
      TSP(I,J,K) = 0.0
```

```
      DO 61 M = 1,5
61    TSP(I,J,K) = TSP(I,J,K) + DGA(I,J,K)/KGA*RGA1(M,J,K)*IDTGA(I,J,K)
      GO TO 600
70    CALL DELDD (EDF(I,J,K),GA(I,J,K),RGA2(1,J,K),DGA(I,J,K),IDTGA
     1           (I,J,K),DT,KGA,AR(I,J,K))
      TSP(I,J,K) = 0.0
      DO 71 M = 1,5
71    TSP(I,J,K) = TSP(I,J,K) + DGA(I,J,K)/KGA*RGA2(M,J,K)*IDTGA(I,J,K)
      GO TO 600
80    CALL DELDD (EDF(I,J,K),GA(I,J,K),RGA3(1,J,K),DGA(I,J,K),IDTGA
     1           (I,J,K),DT,KGA,AR(I,J,K))
      TSP(I,J,K) = 0.0
      DO 81 M = 1,5
81    TSP(I,J,K) = TSP(I,J,K) + DGA(I,J,K)/KGA*RGA3(M,J,K)*IDTGA(I,J,K)
      GO TO 600
600   CONTINUE
      AMP(I,J,K) = AMP(I,J,K) + DT*((1.0 - RRF(I,J,K))*AR(I,J,K))
700   CONTINUE
      YZ(I,J) = (GZS(I,J) - GZSTM1(I,J))/(100. + GZSTM1(I,J))
      GZSTM1(I,J) = GZS(I,J)
      YZD(I,J) = YZ(I,J) + TABLIE(VADF8,SMALL,DIFDF1,KDF1,BEXD(I,J))
C  DISTRIBUTED LAG EXTENSION BUDGET
      BEXD(I,J) = BEXD(I,J) + DT*(BBXIJ(I,J) - BEXD(I,J))
800   CONTINUE
900   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FDYLD                                                  FDYLD
      COMMON /CONTR/  DT,DTP,UTY,FINEDT,IALT,IALTEX(3),IDT,IPCBD,       CONTR
     1                IDROTH,IPRP(6),IPRPHD,IRUN,ISENS,ITIME,IYEAR,     CONTR
     2                JPER,NCUM,NCROP,NDTPOP,NTDPR2,NREGN,NRUN,NT,      CONTR
     3                NTIME,NYEARS,NYRPR2,T,YEAR,YEARAG,YEARD,NCOMAG    CONTR
      COMMON /VAIC/ FXDM1(3,13,3), FX(3,13,3),  FXD(3,13,3),PXD(3,3),   VAIC
     1              IBEXYR(3,13,5),RD(3,13),    YD(3,13),    ACTC(3,13),VAIC
     2              GZSTM1(3,13),  RAM(3),      UCIS(3),     BEXD(3,13),VAIC
     3              AMP(3,13,5),   FLBD(3,13,2),PITP1(3),    PITP2(3),  VAIC
     4              TSP(3,13,5),   PROFTY(3,13),PITP3(3),    PITP4(3),  VAIC
     5              TDP(3,13,5),   CSLP(3),     PIT1(3),     PIT2(3),   VAIC
     6              RGA1(5,13,5),  DRDP(3),     PIT3(3),     PIT4(3),   VAIC
     7              RGA2(5,13,5),  UCSUL(3),    D1TP(3,4),   D2TP(3,4), VAIC
     8              RGA3(5,13,5),  RCP(3),      RDP(3),      RCU(3),    VAIC
     9              DGA(3,13,5),   RIU(3),      RTD(3),      RUD(3),    VAIC
     1              RINT(5,3,8),   STRGP(3,8),  DSC(3,8),    S(3,8),    VAIC
     2              OSUL(3),       ULIG(3),     TL(3,8),     GLIRD(3)   VAIC
      COMMON /PTSF/ PAVG(3,13),  A(3,13),     TA(3),      PX(3,3),      PTSF
     1              ASOR(13),    SZC(3,13),   RSP(3,13),  AGREV(3,13),  PTSF
     2              PXDM1(3,3),  PDM1(3,13),  TLAND(3),   YZD(3,13),    PTSF
     3              ACTCM1(3,13),SCR(3,7),    APSC(3,8),  HAP(3,2),     PTSF
     4              SLDR(3,2),   STLAND,      STA,        SAGBEV(3)     PTSF
      COMMON /VPRT/ TPLAND(3),  TULAND(3),  TCPA(3,8),  SFUCEY(3,13),   VPRT
     1              TCPD(3,8),  QTZS(3,13), GZS(3,13),  PIEYLD(3,13),   VPRT
     2              QZ(3,13,5), QTZ(3,13,5),TREV(3),    ACEYYY(3,13),   VPRT
     3              TVC(3),     CC(3),      TPCOST(3),  YZDYYY(3,13),   VPRT
     4              TNFIN(3),   TPP(3,13),  STPP(13),   SCEYYY(3,13),   VPRT
     5              TFOK(3),    TGL(3),     TPVL1(3),   SYNLAN(3,13),   VPRT
     6              TPVL2(3),   YLD(3,13),  AYLD(13),   AFX(13,3),      VPRT
     7              ATFLB(13),  AFLB(13,2), TFLB(3,13), FLB(3,13,2),    VPRT
     8              STREV,      STVC,       SUCIS,      SCC,            VPRT
     9              STCOST,     STNFIN,     STFOK,      STGL,           VPRT
     1              STPVL1,     STPVL2,     SFXO(3,13), SSFXO(3),       VPRT
     2              SSFX(3),    FOK(3),     GL(3),      PVL1(3),        VPRT
     3              PVL2(3)                                             VPRT.
      DIMENSION ALP(3,13,3), SALP(3,13),   POR(3,13),   PXDR(3,3),      FDYLD
     1          ACTCR(3,13), SPPEFD(3),    FPCFDS(3,13),PPEFD(3,13,3),  FDYLD
     2          SFPEFD(3),   BAP(3,13,3),  SBAP(3),     EFDPP(3,13,3),  FDYLD
     3          AYZ(3,13,3), SVBFD(3),     VEFD(3,13,3),FPEFD(3,13,3),  FDYLD
     4          SSCEFD(3),   PIUR(3,13,3), AACP(3,13,3),EFDOP(3,13,3),  FDYLD
     5          APIU(3,13,3),SPIFD(3),     BAPA(3),     FPCFD(3,13,3),  FDYLD
     6          BAPB(3),     BAPC(3),      BAPD(3),     EFDCP(3,13,3),  FDYLD
     7          RAMT1(3),    RAMT2(3),     RAMT3(3),    FPFDS(3,13,3),  FDYLD
     8          RAMT4(3),    APP1(3),      APP2(3),     SCEFD(3,13,3),  FDYLD
     9          FDPP(3,13,3),FXR(3,13,3),  SACEFD(3),   ASC1(3,13,7),   FDYLD
     1          SCEYLD(3,13),YLDPC(3,13),  ACEYLD(3,13),ASC2(3,13,7),   FDYLD
     2          GLIRA(3),    PIEFD(3,13),  GLIR(3),     ASC3(3,13,7),   FDYLD
     3          VAE1(9),     VAE2(7),      VAE3(5),     ACEFD(3,13,3),  FDYLD
     4          VAE4(7),     ADFDE2(3,13), ADFDE3(3,13),PIFDS(3,13,3),  FDYLD
     5          ADFDE4(3,13),EFDCPS(3,13), YLDPB(3,13), BCEFD(3,13,3),  FDYLD
     6          FPCFDS(3,13),PSC(3,8),     PSCP(3,8),   FUCEY(3,13,3),  FDYLD
     7          SCEYDD(3,13),YZDYDD(3,13), ACEYDD(3,13),YLDPA(3,13,7),  FDYLD
     8          SFX(3,3),    PXB(3,13,3),  FXQ(3,13,3), ADFDE1(3,13,3)  FDYLD
      DIMENSION ADFDE5(3,13,3),ALLPA(3,13,7), SBEAPP(3),    SFPOFD(3),  FDYLD
     1          ALLPB(3,13,2), BEAPP(3,13,3), PXX(3,13,3),  SPXX(3),    FDYLD
     2          SBEAP1(3,13,3),SBEAP2(3,13,3),SSPXX(3),     AAYLD(13),  FDYLD
     3          SBEAP3(3,13,3),SBEAP4(3,13,3),AAFX(13,3),   FXM1(3,13,3),FDYLD
     4          SBEAP5(3,13,3),SBEAP6(3,13,3),YDM1(3,13),   RAMM1(3),   FDYLD
     5          SBEAP7(3,13,3),SBEAP8(3,13,3),SVIR(3),      PVLIR1(3),  FDYLD
     6          FLBFD1(3,13,2),FLBFD2(3,13,2),PVLIR2(3),    RAMR(3),    FDYLD
     7          FLBFD3(3,13,2),FLBPA1(3,13,2),UVC(3,13),    SVC(3),     FDYLD
```

```
     8          FLBPA2(3,13,2),FLBPA3(3,13,2),REV(3,13),   TFLBP(3,13),
     9          FLBYZD(3,13,2),FLBPB(3,13,2),
     1          FLBACE(3,13,2),FLBPC(3,13,2), AAFLB(13,2), AAYELB(13),
     2          FLBSCE(3,13,2),FLBPD1(3,13,7),
     3          FLBPD2(3,13,7),FLBPRP(3,13,2)
      DIMENSION FOKPA(3),GLOB(3) ,YLDM1(3,13)
      DATA SHALE1,SHALE2,SHALE3,SHALE4/ -0.2, 0.0, 0.0, 0.0/
      DATA DIFFE1,DIFFE2,DIFFE3,DIFFE4/ 0.05, 0.1, 0.5, 100./
      DATA KE1,KE2,KE3,KE4/ 8, 6, 4, 6/
      DATA VAE1/ 0.3, 0.264, 0.165, 0.03, 0.0, 0.05, 0.275, 0.44, 0.5/
      DATA VAE2/ 0.0, 0.02, 0.05, 0.13, 0.235, 0.285, 0.3/
      DATA VAE3/ 0.0, 0.035, 0.15, 0.265, 0.3/
      DATA VAE4/ 0.0, 0.035, 0.09, 0.21, 0.325, 0.375, 0.4/
      DATA AYZ/ 3*2.0, 3*1.5, 3*1.5, 3*1.5, 3*2.0, 3*1.0, 3*2.0, 3*2.0,
     1          3*1.0, 3*2.0, 3*1.0, 3*1.0, 3*2.0,
     2          3*0.5, 3*0.3, 3*0.3, 3*0.3, 3*0.5, 3*0.3, 3*0.5, 3*0.3,
     3          3*0.3, 3*0.0, 3*0.3, 3*0.3, 3*0.0,
     4          3*0.3, 3*0.2, 3*0.2, 3*0.2, 3*0.5, 3*0.2, 3*0.5, 3*0.2,
     5          3*0.5, 3*0.2, 3*0.5, 3*0.2, 3*0.1/
      DATA YLDPA/
     2            3*0.2,      0.0,      0.01,      0.0,      0.0,
     3              0.01,     0.0,   12*0.0,       0.0,      0.02,
     4              0.0,    3*0.0,    3*0.015,   9*0.0,
     5            3*0.159, 24*0.0,    3*0.01,    9*0.0,    3*0.107,
     6           36*0.0,   39*0.0,    3*0.1,     9*0.01,  15*0.0,
     7            3*0.02,   9*0.0,   33*0.0,     3*0.0,   12*0.03,
     8            3*0.15,   3*0.4,    3*0.2,     3*0.15,   3*0.4,
     9            6*0.1,    3*0.0/
      DATA ASC1/
                                      3*0.15,     0.0,       0.01,
     1              0.0,      0.0,      0.01,     0.0,     9*0.0,
     2              0.0,      0.03,     0.0,      0.0,       0.03,
     3              0.0,    3*0.0,      0.0,      0.02,      0.0,
     4            9*0.0,    3*0.1,   36*0.0,    3*0.05,   36*0.0,
     5            3*0.1,      0.0,      0.01,     0.0,       0.0,
     6              0.01,     0.0,    9*0.0,      0.0,       0.03,
     7              0.0,      0.0,      0.03,     0.0,     3*0.0,
     8              0.0,      0.02,     0.0,    9*0.0,     3*0.1,
     9              0.0,      0.02,     0.0,      0.0,       0.02,
     1              0.0,   30*0.0,    3*0.0,      0.0,       0.02,
     2              0.0,      0.0,      0.02,     0.0,     3*0.02,
     3            3*0.05,   3*0.01,   6*0.05,   3*0.01,    3*0.05,
     4            6*0.01,   3*0.0,    3*0.0,      0.0,       0.01,
     5              0.0,      0.0,      0.01,     0.0,     3*0.3,
     6            3*0.5,    3*0.2,    6*0.5,    3*0.2,     3*0.5,
     7            3*0.1,    3*0.05,   3*0.0/
      DATA ASC2/
                                      3*0.08,  36*0.0,     3*0.04,
     1           36*0.0,    3*0.02,  36*0.0,    3*0.05,      0.0,
     2              0.01,     0.0,      0.0,      0.01,      0.0,
     3           30*0.0,    3*0.05,     0.0,      0.02,      0.0,
     4              0.0,      0.02,     0.0,   33*0.0,       0.0,
     5              0.01,     0.0,      0.0,      0.01,      0.0,
     6            3*0.01,   3*0.02,   3*0.01,   3*0.02,    6*0.01,
     7            3*0.0,    3*0.01,   6*0.0,    3*0.0,       0.0,
     8              0.01,     0.0,      0.0,      0.01,      0.0,
     9            3*0.1,    3*0.15,   9*0.1,    3*0.05,    3*0.0,
     1            3*0.02,   6*0.0/
      DATA ASC3/
                                      3*0.08,     0.0,       0.01,
     1              0.0,      0.0,      0.01,     0.0,    30*0.0,
     2            3*0.04,  36*0.0,    3*0.02,  36*0.0,     3*0.05,
     3              0.0,      0.01,     0.0,      0.0,       0.01,
     4              0.0,   30*0.0,    3*0.05,     0.0,       0.02,
```

```
     5           0.0,       0.0,       0.02,      0.0,    30*0.0,
     6         3*0.0,   12*0.02,     3*0.01,    3*0.02,   15*0.01,
     7         3*0.0,     3*0.0,     6*0.01,    3*0.1,     3*0.15,
     8         9*0.1,    6*0.05,     3*0.02,    3*0.03,    3*0.0/
      DATA AACP/ 12*0.0,  3*0.5,  15*0.0, 3*0.5,  6*0.0,
     1           12*0.0,  3*0.5,  15*0.0, 3*0.5,  6*0.0,
     2           12*0.0,  3*0.5,  15*0.0, 3*0.5,  6*0.0/
      DATA YLDPB/12*0.0, 3*2.0, 15*0.0, 3*3.0, 6*0.0/
      DATA PXB/ 39*1.5, 39*1.3, 39*1.0/
      DATA APP1,APP2/ 3*0.15, 3*0.10/
      DATA PSC/ 3*0.02,3*0.01,3*0.02,3*0.02,3*0.003,6*0.02,3*0.003/
      DATA ALLPA/ 273*1.0/
      DATA ALLPB/ 3*1.0, 0.0, 0.3,2*0.0, 0.2,  14*0.0, 0.2, 5*0.0, 0.1,
     1          10*0.0,
     2          3*0.0, 3*0.6, 3*0.1, 3*0.5, 6*0.1, 3*0.0, 3*0.2,
     3          12*0.1,3*0.0/
      DATA  FLBPA1/ 39*0.02,39*0.01/
      DATA FLBPA2/ 39*0.02,39*0.01/
      DATA  FLBPA3/ 39*-0.50,39*-0.50/
      DATA FLBPB / 39*0.05, 39*0.03/
      DATA  FLBPC/ 12*0.0,3*0.1,15*0.0,3*0.1,6*0.0,12*0.0,3*0.1,15*0.0,
     1           3*0.1,6*0.0/
      DATA  FLBPD1/3*-2.75,     -0.50,     -1.20,     -0.50,     -0.50,
     1             -1.00,     -0.50, 12*0.0,    3*-0.40,   3*0.0,
     2          3*-0.40,   9*0.0,
     3          3*-1.20, 36*0.0,    39*0.0,
     4          3*-2.75,     -0.75,     -1.50,     -0.75,     -0.50,
     5             -1.20,     -0.50, 12*0.0,    3*-0.50,   3*0.0,
     6          3*-0.50,   9*0.0,
     7          3*-1.50,     -0.50,     -2.50,     -0.50,     -0.50,
     8             -1.25,     -0.30, 12*0.0,    3*-0.50,   3*0.0,
     9          3*-1.25,   9*0.0,
     1          3*0.0,    33*-3.00,  3*0.0,
     2          3*0.0,    33*-1.50,  3*0.0/
      DATA  FLBPD2/3*-2.75,     -0.50,     -1.20,     -0.50,     -0.50,
     1             -1.00,     -0.50, 12*0.0,    3*-0.40,   3*0.0,
     2          3*-0.40,   9*0.0,
     3          3*-1.20, 36*0.0,    39*0.0,
     4          3*-2.75,     -0.75,     -1.50,     -0.75,     -0.50,
     5             -1.20,     -0.50, 12*0.0,    3*-0.50,   3*0.0,
     6          3*-0.50,   9*0.0,
     7          3*-1.50,     -0.50,     -2.50,     -0.50,     -0.50,
     8             -1.25,     -0.30, 12*0.0,    3*-0.50,   3*0.0,
     9          3*-1.25,   9*0.0,
     1          3*0.0,    33*-3.00,  3*0.0,
     2          3*0.0,    33*-1.50,  3*0.0/
      DATA  TFLBP/ 3*2.131,6*1.777,3*3.418,3*3.477,3*4.660,3*6.193,
     1             3*3.229,3*2.387,3*3.505,3*11.889,3*4.164,3*2.00/
      DATA FOKPA,FOKPX/ 0.15,  0.12,  0.17,  -0.02/
      DATA GLIRB,GLPA/ 0.08,    0.03/
      DATA PGLIR1,PGLIR2, PGLIR3,GLIRR, DAB /
     1      0.9, 2.0,   3.0,  0.06,      3.0/
      DATA GLPB/ 60., 30., 40./
      R1 = RANF(1)
      DO 1000 I = 1,3
      GLIR(I) = GLIRD(I)
      SVIR(I) = PGLIR1*GLIR(I)
      PVLIR1(I) = PGLIR2*GLIR(I)
      PVLIR2(I) = PGLIR3*GLIR(I)
      GLIRA(I) = GLIRB + (R1*GLIRR-0.5*GLIRR)
      FOK(I) = FOKPA(I)*SAGREV(I)*EXP(FOKPX*T)
```

```
      GL(I) = GLPR(I)*EXP(GLPA*T)                                       FDYLD
      SBEAPP(I) = 0.0                                                   FDYLD
      SPPEFD(I) = 0.0                                                   FDYLD
      SFPOFD(I) = 0.0                                                   FDYLD
      SFPEFD(I) = 0.0                                                   FDYLD
      SBAP(I) = 0.0                                                     FDYLD
      SVEFD(I) = 0.0                                                    FDYLD
      SSCEFD(I) = 0.0                                                   FDYLD
      SACEFD(I) = 0.0                                                   FDYLD
      SPIFD(I) = 0.0                                                    FDYLD
C  PRODUCTIVITY COEFFICIENTS                                            FDYLD
      DO 101  J = 1,13                                                  FDYLD
      SALP(I,J) = 0.0                                                   FDYLD
      PIEFD(I,J) = 0.0                                                  FDYLD
      FPCFDS(I,J) = 0.0                                                 FDYLD
      DO 107  L = 1,3                                                   FDYLD
      IF (J.EQ. 5 .OR. J .EQ. 12) GO TO 100                             FDYLD
      ALP(I,J,L) = FXD(I,J,L)*PXD(I,L)/ (YD(I,J)*PD(I,J))               FDYLD
      GO TO 103                                                         FDYLD
 100  ALP(I,J,L) = FXD(I,J,L)*PXD(I,L)/ (YD(I,J)*PD(I,J))*0.5           FDYLD
C  SUM OF PRODUCTIVITY COEFFICIENTS                                     FDYLD
 103  SALP(I,J) = SALP(I,J) + ALP(I,J,L)                                FDYLD
C  RELATIVE CHANGE IN PRODUCT PRICES                                    FDYLD
      PDR(I,J) = (PD(I,J) - PDM1(I,J))/PDM1(I,J)                        FDYLD
C  RELATIVE CHANGE IN FACTOR PRICE                                      FDYLD
      PXDR(I,L) = (PXD(I,L) - PXDM1(I,L))/PXDM1(I,L)                    FDYLD
C  RELATIVE CHANGE IN TREE CROP AGE COMPOSITION AND PAST INPUT USE      FDYLD
      IF (J.EQ.5 .OR. J.EQ.11) GO TO 106                                FDYLD
      GO TO 107                                                         FDYLD
 106  ACTCR(I,J) = ACTC(I,J) - ACTCM1(I,J)                              FDYLD
 108  PIUR(I,J,L) = (FXD(I,J,L) - FXDM1(I,J,L))/FXDM1(I,J,L)            FDYLD
 107  CONTINUE                                                          FDYLD
C  ADJUSTED FACTOR OF FACTOR DEMAND ELASTICITY WRT CROP SIZE            FDYLD
      ADFDE2(I,J) = TABLIE (VAE2,SMALE2,DIFFE2,KE2,SZC(I,J))            FDYLD
C  ADJUSTED FACTOR OF FACTOR DEMAND ELASTICITY WRT REGIONAL SPECIALIZATI FDYLD
      ADFDE3(I,J) = TABLIE (VAE3,SMALE3,DIFFE3,KE3,RSP(I,J))            FDYLD
C  ADJUSTED FACTOR OF FACTOR DEMAND ELASTICITY WRT PROFITABILITY        FDYLD
      ADFDE4(I,J) = TABLIE (VAE4,SMALE4,DIFFE4,KE4,PROFTY(I,J))         FDYLD
C  ADJUSTED FACTOR OF FACTOR DEMAND ELASTICITY WRT FACTOR PRICE         FDYLD
      DO 101 L = 1,3                                                    FDYLD
      ADFDE1(I,J,L) = TABLIE (VAE1,SMALE1,DIFFE1,KE1,PXDR(I,  L))       FDYLD
 112  CONTINUE                                                          FDYLD
C  ADJUSTED FACTOR DEMAND ELASTICITY WRT OWN FACTOR PRICE               FDYLD
 101  EFDOP(I,J,L) = ADFDE1(I,J,L)*(1.0 + ADFDE2(I,J) + ADFDE3(I,J) +   FDYLD
     1               ADFDE4(I,J))                                       FDYLD
C  ADJUSTED FACTOR DEMAND ELASTICITY WRT OWN AS WELL AS CROSS PRICE     FDYLD
      DO 116 J = 1,13                                                   FDYLD
      DO 116 L = 1,3                                                    FDYLD
      EFDCP(I,J,L) = ALP(I,J,L)/(1.0 - SALP(I,J))*EFDOP(I,J,L)          FDYLD
C  FACTOR DEMAND ELASTICITY WRT PRODUCT PRICE                           FDYLD
      ADFDE5(I,J,L) = TABLIE (VAE1,SMALE1,DIFFE1,KE1,PDR(I,J))          FDYLD
      EFDPP(I,J,L) = ADFDE5(I,J,L)*(1.0 + ADFDE2(I,J) + ADFDE3(I,J) +   FDYLD
     1               ADFDE4(I,J))/(1.0 - SALP(I,J))                     FDYLD
C  PRODUCT PRICE EFFECT ON FACTOR DEMAND                                FDYLD
 117  BEAPP(I,J,L) = PX(I,L)*FXD(I,J,L)                                 FDYLD
 118  SBEAPP(I) = SBEAPP(I) + BEAPP(I,J,L)                              FDYLD
      PPEFD(I,J,L) = EFDPP(I,J,L)*PDR(I,J)                              FDYLD
 120  SBEAP1(I,J,L) = BEAPP(I,J,L)*PPEFD(I,J,L)                         FDYLD
 121  SPPEFD(I) = SPPEFD(I) + SBEAP1(I,J,L)                             FDYLD
C  OWN PRICE EFFECT ON FACTOR DEMAND                                    FDYLD
      FPEFD(I,J,L) = EFDOP(I,J,L)*PXDR(I,L)                             FDYLD
```

```
 122  SBEAP2(I,J,L) = BEAPP(I,J,L)*FPEFD(I,J,L)
      SFPOFD(I) = SFPOFD(I) + SBEAP2(I,J,L)
C  GROSS PRICE EFFECT ON FACTOR DEMAND
 123  FPCFD(I,J,L) = BFDCP(I,J,L)*PXDR(I,L)
 116  FPCFDS(I,J) = FPCFDS(I,J) + FPCFD(I,J,L)
      DO 125 J = 1,13
      DO 126 L = 1,3
      SBEAP3(I,J,L) = BEAPP(I,J,L)*FPCFDS(I,J)
C  SUM OF INDIVIDUAL FACTOR PRICE EFFECT
      FPFDS(I,J,L) = FPEFD(I,J,L) + FPCFDS(I,J)
 127  SFPEFD(I) = SFPEFD(I) + SBEAP3(I,J,L)
C  COEFFICIENT OF TERM OF CHANGE IN MVP OF CAPITAL
      BAP(I,J,L) = 1.0/(1.0 - SALP(I,J))
 128  SBEAP8(I,J,L) = BEAPP(I,J,L)*BAP(I,J,L)
 129  SBAP(I) = SBAP(I) + SBEAP8(I,J,L)
C  VARIETAL CHANGE EFFECT ON FACTOR DEMAND
      VEFD(I,J,L) = AYZ(I,J,L)*YZD(I,J)
 130  SBEAP4(I,J,L) = BEAPP(I,J,L)*VEFD(I,J,L)
 131  SVEFD(I) = SVEFD(I) + SBEAP4(I,J,L)
C  STRUCTURAL CHANGE EFFECT ON FACTOR DEMAND
 126  SCEFD(I,J,L) = 0.0
      DO 133 K = 1,7
      SCEFD(I,J,1) = SCEFD(I,J,1) + ASC1(I,J,K)*SCR(I,K)*ALLPA(I,J,K)
      SCEFD(I,J,2) = SCEFD(I,J,2) + ASC2(I,J,K)*SCR(I,K)*ALLPA(I,J,K)
 133  SCEFD(I,J,3) = SCEFD(I,J,3) + ASC3(I,J,K)*SCR(I,K)*ALLPA(I,J,K)
      DO 125 L = 1,3
      SBEAP5(I,J,L) = BEAPP(I,J,L)*SCEFD(I,J,L)
 134  SSCEFD(I) = SSCEFD(I) + SBEAP5(I,J,L)
C  AGE COMPOSITION CHANGE EFFECT ON FACTOR DEMAND
      IF (J.EQ.5 .OR. J.EQ.11) GO TO 135
      GO TO 125
 135  ACEFD(I,J,L) = AACP(I,J,L)*ACTCR(I,J)
      SBEAP6(I,J,L) = BEAPP(I,J,L)* ACEFD(I,J,L)
 137  SACEFD(I) = SACEFD(I) + SBEAP6(I,J,L)
C  PAST INPUT USE EFFECT ON FACTOR DEMAND
 139  APIU(I,J,L) = ALP(I,J,L)/(1.0 - SALP(I,J))
      PIEFD(I,J) = PIEFD(I,J) + APIU(I,J,L)*PIUR(I,J,L)
 125  CONTINUE
      DO 147 JJ = 1,2
      DO 147 L = 1,3
      IF (JJ.EQ.1) J = 5
      IF (JJ.EQ.2) J = 11
      SBEAP7(I,J,L) = BEAPP(I,J,L)*PIEFD(I,J)
 144  PIFDS(I,J,L) = PIEFD(I,J)
 146  SPIFD(I) = SPIFD(I) + SBEAP7(I,J,L)
 147  CONTINUE

C
C  COMPUTE MVP OF CAPITAL
C
      RAMM1(I) = RAM(I)
      BAPA(I) = RAMM1(I)/SBAP(I)
      BAPB(I) = SBEAPP(I) + SFPEFD(I) - SFPOFD(I) - SFCEFD(I) +
     1          SVEFD(I) + SSCEFD(I) + SACEFD(I) + SPIFD(I)
C  FIRST TRIAL WITH FARMERS OWN CAPITAL
      RAMT1(I) = BAPA(I)*BAPB(I) + RAMM1(I) - BAPA(I)*(FOK(I))
      IF (RAMT1(I).GT.(1.0 + SVIR(I))) GO TO 151
      RAM(I) = 1.0 + SVIR(I)
      GO TO 160
C  SECOND TRIAL WITH GOVT LOAN IN ADDITION TO FARMERS OWN CAPITAL
 151  RAMT2(I) = BAPA(I)*BAPB(I) + RAMM1(I) - BAPA(I)*(FOK(I) + GL(I))
```

```
      IF (RAMT2(I) - (1.0 + GLIR(I))) 551,552,152
 551  BAM(I) = 1.0 + RVIR(I)
      GO TO 160
 552  BAM(I) = 1.0 +  GLIR(I)
      GO TO 160
C  THIRD TRIAL WITH PRIVATE LUAN IN AUDITION TO BOTH SOURCES ABOVE
 152  BAMT3(I) = BAPA(I)+BAPB(I) + RAMM1(I) - BAPA(I)*(FOK(I) + GL(I))
     1            *(1.0 + APP1(I))
      IF (RAMT3(I) - (1.0 + PVLIR1(I))) 553,554,153
 553  RAM(I) = 1.0 + GLIR(I)
      GO TO 160
 554  RAM(I) = 1.0 + PVLIR1(I)
      GO TO 160
C  FOURTH TRIAL WITH PRIVATE LOAN WITH MORE WORSE TERMS
 153  RAMT4(I) = BAPA(I)+BAPB(I) + RAMM1(I) - BAPA(I)*(FOK(I) + GL(I))
     1            *(1.0 + APP1(I) +APP2(I))
      IF ( RAMT4(I) - (1.0 + PVLIR2(I))) 555,556,556
 555  BAM(I) = 1.0 + PVLIR1(I)
      GO TO 160
 556  BAM(I) = 1.0 + PVLIR2(I)
 160  CONTINUE
C
C  COMPUTE INDIVIDUAL FACTOR DEMAND
C
      RAMR(I) = (RAM(I) - RAMM1(I))/RAMM1(I)
      DO 161 J = 1,13
      SCEYDD(I,J) = 0.0
      YZDYDD(I,J) = 0.0
      SYNLAN(I,J) = 0.0
      ACEYDD(I,J) = 0.0
      SFUCEY(I,J) = 0.0
      SCEYLD(I,J) = 0.0
      IF (J.EQ.5 .OR. J.EQ.11) GO TO 158
      PIEFD(I,J) = 0.0
 158  CONTINUE
      DO 162 L = 1,3
      IF (J.EQ.5 .OR. J.EQ.11) GO TO 159
      ACEFD(I,J,L) = 0.0
 159  CONTINUE
      BCEFD(I,J,L) = BAP(I,J,L)*RAMR(I)
      FDPP(I,J,L) = 1.0 - PPEFD(I,J,L) - FPEFD(I,J,L) - FPCFDS(I,J) -
     1                    BCEFD(I,J,L) + VEFD(I,J,L) + SCEFD(I,J,L) +
     2                    ACEFD(I,J,L) + PIEFD(I,J)
      FXM1(I,J,L) = FX(I,J,L)
 163  FX(I,J,L) = FDPP(I,J,L)*FXM1(I,J,L)
C
C  COMPUTE INDIVIDUAL CROP YIELD LEVEL
C
      FXR(I,J,L) = (FX(I,J,L) - FXM1(I,J,L))/FXM1(I,J,L)
      DO 166 M = 1,2
166   SYNLAN(I,J)= SYNLAN(I,J) + (1.0 - HAP(I,M))*SLDR(I,M)*ALLPB(I,J,M)
      SCEYDD(I,J) = SCEYDD(I,J) + SCEFD(I,J,L)*ALP(I,J,L)
      ACEYDD(I,J) = ACEYDD(I,J) + ALP(I,J,L)*ACEFD(I,J,L)
165   YZDYDD(I,J) = YZDYDD(I,J) + VEFD(I,J,L)*ALP(I,J,L)
 170  FUCEY(I,J,L) = ALP(I,J,L)*FXR(I,J,L)
 172  SFUCEY(I,J) = SFUCEY(I,J) + FUCEY(I,J,L)
      DO 174 K = 1,7
174   SCEYLD(I,J) = SCEYLD(I,J) + YLDPA(I,J,K)*SCR(I,K)*ALLPA(I,J,K)
 162  CONTINUE
      PIEYLD(I,J) = 0.0
 161  CONTINUE
```

```
      DO 177 J = 1,13
      IF (J.EQ.5 .OR. J.EQ.11) GO TO 175
      ACEYLD(I,J) = 0.0
      RIEYLD(I,J) = 0.0
      GO TO 178
175   ACEYLD(I,J) = YLDPB(I,J)*ACTCR(I,J)
      DO 176 L = 1,3
176   RIEYLD(I,J) = RIEYLD(I,J) + ALP(I,J,L)*PIUR(I,J,L)
178   YZDYYY(I,J) = YZD(I,J) - YZDYDD(I,J)
      SCEYYY(I,J) = SCEYLD(I,J) - SCEYDD(I,J)
      ACEYYY(I,J) = ACEYLD(I,J) - ACEYDD(I,J)
      IF (YZDYYY(I,J).LT.0.0) YZDYYY(I,J) = 0.0
      IF (SCEYYY(I,J).LT.0.0) SCEYYY(I,J) = 0.0
      IF (ACEYYY(I,J).LT.0.0) ACEYYY(I,J) = 0.0
      YLDPC(I,J) = 1.0 + SFUCEY(I,J) + RIEYLD(I,J) + ACEYYY(I,J) +
     1             YZDYYY(I,J) + SCEYYY(I,J) - SYNLAN(I,J)
      YLDM1(I,J) = YLD(I,J)
      YLD(I,J) = YLDPC(I,J)*YLDM1(I,J)
C
C  COMPUTE LABOR DEMAND BY SEASONS
C
      DO 401 N = 1,2
      FLBFD1(I,J,N) = FLBPA1(I,J,N)*FXR(I,J,1)
      FLBFD2(I,J,N) = FLBPA2(I,J,N)*FXR(I,J,2)
      FLBFD3(I,J,N) = FLBPA3(I,J,N)*FXR(I,J,3)
      FLBYZD(I,J,N) = FLBPB(I,J,N)*YZD(I,J)
      IF (J.EQ.5  .OR. J.EQ.11) GO TO 402
      GO TO 403
402   FLBACE(I,J,N) = FLBPC(I,J,N)*ACTCR(I,J)
      GO TO 404
403   FLBACE(I,J,N) = 0.0
404   CONTINUE
401   CONTINUE
      FLBSCE(I,J,1) = 0.0
      FLBSCE(I,J,2) = 0.0
      DO 405 K = 1,7
      FLBSCE(I,J,1) = FLBSCE(I,J,1) + FLBPD1(I,J,K)*SCB(I,K)*
     1                ALLPA(I,J,K)
405   FLBSCE(I,J,2) = FLBSCE(I,J,2) + FLBPD2(I,J,K)*SCB(I,K)*
     1                ALLPA(I,J,K)
      DO 406 N = 1,2
      FLBPPP(I,J,N) = FLBFD1(I,J,N) + FLBFD2(I,J,N) + FLBFD3(I,J,N) +
     1                FLBYZD(I,J,N) + FLBACE(I,J,N) + FLBSCE(I,J,N)
406   FLB(I,J,N) = (1.0 + FLBPPR(I,J,N))*FLB0(I,J,N)
177   TFLB(I,J) = (FLB(I,J,1) + FLB(I,J,2))*TFLBP(I,J)
C
C  COMPUTE PRODUCTION COST AND TOTAL REVENUE
C
C  VARIABLE COST
      TVC(I) = 0.0
      SVC(I) = 0.0
      DO 180 J = 1,13
      UVC(I,J) = 0.0
      DO 181 L = 1,3
      UVC(I,J) = UVC(I,J) + PX(I,L)*FX(I,J,L)
182   PXX(I,J,L) = SBEAPB(I,J,L)*RAMR(I)
181   CONTINUE
      SVC(I) = SVC(I) + UVC(I,J)
183   TVC(I) = TVC(I) + UVC(I,J)*A(I,J)
180   CONTINUE
C  USER COST FOR INFRASTRUCTURE
```

```
      DO 184 K = 1,8
      PSCP(I,K)=APSC(I,K)*PSC(I,K)
  184 UCIS(I) = UCIS(I) + PSCP(I,K)+DSC(I,K)
C CREDIT COST
      IF (SVC(I).LE.FOK(I)) FOK(I) = SVC(I)
      IF (SVC(I).LE.(FOK(I) + GL(I)))GL(I) = SVC(I) - FOK(I)
      PVL1(I) = SVC(I) - FOK(I) - GL(I)
      IF (PVL1(I).LE.0.0) PVL1(I) = 0.0
      IF (PVL1(I).GT. (FOK(I) + GL(I))*(      APP1(I)))PVL1(I) = (FOK(I)
     1    + GL(I))*(      APP1(I))
      PVL2(I) = SVC(I) - FOK(I) - GL(I) - PVL1(I)
      IF (PVL2(I).LE. 0.0) PVL2(I) = 0.0
      CC(I) = (SVIR(I)*FOK(I) + GLIR(I)*GL(I) + PVLIR1(I)*PVL1(I) +
     1        PVLIR2(I)*PVL2(I))/13.0*TA(I)
      TPCOST(I) = TVC(I) + UCIS(I) + CC(I)
      TFOK(I) = FOK(I)/13.0*TA(I)
      TGL(I) = GL(I)/13.0*TA(I)
      TPVL1(I) = PVL1(I)/13.0*TA(I)
      TPVL2(I) = PVL2(I)/13.0*TA(I)
      SPXX(I) = 0.0
      TREV(I) = 0.0
      DO 186 J = 1,13
      TPP(I,J) = YLD(I,J)*A(I,J)
      REV(I,J) = PAVG(I,J)*TPP(I,J)
      TREV(I) = TREV(I) + REV(I,J)
      DO 186 L = 1,3
      SPXX(I) = SPXX(I) + PXX(I,J,L)
      SSPXX(I) = SBEAPP(I) + SPREFD(I) - SFPOFD(I) - SEPBFD(I) -
     1   SPXX(I) + SVBFD(I) + SSCEFD(I) + SACEFD(I) + SPIFD(I)
  186 CONTINUE
      TNFIN(I) = TREV(I) - TPCOST(I)
C
C COMPUTE DISTRIBUTED LAGS
C
C DISTRIBUTED LAG YIELD
      GLIRD(I) = GLIRD(I) + DT*(GLIRA(I) - GLIRD(I))/DAB
      DO 195 J = 1,13
      YDM1(I,J) = YD(I,J)
      YD(I,J) = YD(I,J) + DT*(YLD(I,J) - YD(I,J))/DAB
      DO 196 L = 1,3
      FXDM1(I,J,L) = FXD(I,J,L)
  196 FXD(I,J,L) = FXD(I,J,L) + DT*(FX(I,J,L) - FXD(I,J,L))/DAB
      DO 197 N = 1,2
      FLBD(I,J,N) = FLBD(I,J,N) + DT*(FLB(I,J,N) - FLBD(I,J,N))/DAB
  197 CONTINUE
  195 CONTINUE
 1000  CONTINUE
C
C COMPUTE  NATIONAL AVERAGES OR TOTALS
C
      DO 201 J = 1,13
      AAYLD(J) = 0.0
      AATFLD(J) = 0.0
      STPP(J) = 0.0
      DO 200 L = 1,3
  200 AAFX(J,L) = 0.0
      DO 201 N = 1,2
  201 AAFLB(J,N) = 0.0
      DO 202 I = 1,3
      DO 202 J = 1,13
      AAYLD(J) = AAYLD(J) + A(I,J)*YLD(I,J)
```

```
      AYLD(J) = AAYLD(J)/ASOR(J)
      AATFLB(J) = AATFLB(J) + A(I,J)*TFLB(I,J)
      ATFLB(J) =  AATFLB(J)/ASOR(J)
      STPP(J) = STPP(J) + TPP(I,J)
      DO 204 L = 1,3
      AAFX(J,L) = AAFX(J,L) + A(I,J)*FX(I,J,L)
 204  AFX(J,L) = AAFX(J,L)/ASOR(J)
      DO 202 N = 1,2
      AAFLB(J,N) = AAFLB(J,N) + A(I,J)*FLB(I,J,N)
 202  AFLB(J,N) = AAFLB(J,N)/ASOR(J)
      STPVL2 = 0.0
      STFOK = 0.0
      STGL = 0.0
      STPVL1 = 0.0
      SSVC = 0.0
      STVC = 0.0
      SUCIS = 0.0
      SCC = 0.0
      STCOST = 0.0
      STREV = 0.0
      STNFIN = 0.0
      SATFLB = 0.0
      DO 203 I = 1,3
      STFOK = STFOK + TFOK(I)
      STGL = STGL + TGL(I)
      STPVL1 = STPVL1 + TPVL1(I)
      STPVL2 = STPVL2 + TPVL2(I)
      SSVC = SSVC + SVC(I)
      STVC = STVC + TVC(I)
      SUCIS = SUCIS + UCIS(I)
      SCC = SCC + CC(I)
      STCOST = STCOST + TPCOST (I)
      STREV = STREV + TREV(I)
 203  STNFIN = STNFIN + TNFIN(I)
      SSTPP = STPP(1) + STPP(2) + STPP(3) + STPP(4) + STPP(6) + STPP(8)
C
C  AGGREGATE INPUT USED IN QUANTITY
C
      DO 205 L = 1,3
      SSFX(L) = 0.0
      SSFXQ(L) = 0.0
      DO 205 I = 1,3
      SFX(I,L) = 0.0
 205  SFXQ(I,L) = 0.0
      DO 206 I = 1,3
      DO 206 J = 1,13
      DO 206 L = 1,3
      SFX(I,L) = SFX(I,L) + FX(I,J,L)
 206  FXQ(I,J,L) = FX(I,J,L)/PXB(I,J,L
      DO 207 I = 1,3
      DO 207 L = 1,3
      SSFX(L) = SSFX(L) + SFX(I,L)
      SFXQ(I,L) = SFXQ(I,L) + FXQ(I,J,
 207  SSFXQ(L) = SSFXQ(L) + SFXQ(I,L)
      DO 208 J = 1,13
      SATFLB = SATFLB + AATFLB(J)
 208  CONTINUE
      SAAFX1 = 0.0
      DO 259 J = 1,13
 259  SAAFX1 = SAAFX1 + AAFX(J,1)
      RETURN
      END
```

```
      FUNCTION TABLIE (VAL,SMALL, DIFF,K,DUMMY)                                DELDT
      DIMENSION VAL(1)                                                         DELDT
      DUM = AMIN1(AMAX1(DUMMY-SMALL,0.0),FLOAT(K)*DIFF)                        DELDT
      I = 1.0 + DUM/DIFF                                                       DELDT
      IF (I.EQ.K+1) I = K                                                      DELDT
      TABLIE = (VAL(I+1)-VAL(I))*(DUM-FLOAT(I-1)*DIFF)/DIFF+VAL(I)             DELDT
      RETURN                                                                   DELDT
      END                                                                      DELDT


      SUBROUTINE DELDD(RINR,ROUTR,CROUTR,DEL,IDT,DT,K,AR                       DELDT
      DIMENSION CROUTR(1)                                                      DELDT
      DEL1 = (DEL*FLOAT(IDT))/(FLOAT(K)*DT)                                    DELDT
      FIDT = FLOAT(IDT)                                                        DELDT
      ROUTR = 0.0                                                              DELDT
      AR = 0.0                                                                 DELDT
      DO 2 J = 1,IDT                                                           DELDT
      BIN = RINR/FLOAT(IDT)                                                    DELDT
      AR = AR + DT*CROUTR(K)                                                   DELDT
      DO 1  I = 1,K                                                            DELDT
      ABC = CROUTR(I)                                                          DELDT
      CROUTR(I) = ABC + (BIN - ABC)/DEL1                                       DELDT
    1 BIN = ABC                                                                DELDT
    2 ROUTR = ROUTR + CROUTR(K)                                                DELDT
      RETURN                                                                   DELDT
      END                                                                      DELDT
```

```
      SUBROUTINE DELLVF(RIN,ROUT,R,STRG,PLR,DEL,DELP,DT,K)
      DIMENSION R(1)
      FK = FLOAT(K)
      B = 1. + (DEL - DELP)/(FK*DT) + PLR*DELP/FK
      IDT = 1. + 2.*DT*FK/DELP*AMAX1(B,J,0)
      A = FK*DT/(DELP*FLOAT(IDT))
      DELP = DEL
      KM1 = K - 1
      DO 20 J = 1, IDT
      DO 10 I = 1,KM1
      R(I) = R(I) + A*(R(I + 1) - B*R(I))
   10 CONTINUE
      R(K) = R(K) + A*(RIN - B*R(K))
   20 CONTINUE
      STRG = 0.0
      DO 30 I = 1,K
      STRG = STRG + R(I)*DEL/FK
   30 CONTINUE
      ROUT = R(1)
      RETURN
      END
*EOR
*EOR
  10/10/74  MSU HUSTLER 2 L239 LSD 36.07  10/08/74
14.31.39.YA28422
14.31.40.JOB READ-  10/10/74 14.13.52.
14.31.40.LEEJHA,CM110000,T99,JC900,L100.
14.31.40.LAST ACCESS- A 12.15 10/10/74
14.31.40.RUNS- 0572 USER DOLLAR BALANCE $00111.45
14.31.40.000010    CARDS READ  VALUE  $0000000.01
14.31.40.CP-PP SEC.      .072-      .011  $      .00
14.31.40.ATTACH,OLDPL,YIELDFINALPL.
14.31.41.OLDPL    - CYCLE 01, YIELDFINALPL
14.31.41.FILE ATTACHED
14.31.41.CP-PP SEC.      .077-      .571  $      .00
14.31.41.UPDATE,F.
14.31.41.NL  035000
14.31.41.RP        00000003  000000000000
14.31.55. UPDATE COMPLETE.
14.31.55.CP-PP SEC.    1.938-     5.227  $      .33
14.31.55.ATTACH,COPYMCF,CMCOPY.
14.31.55.COPYMCF - CYCLE 01, CMCOPY
14.31.55.FILE ATTACHED
14.31.55.CP-PP SEC.    1.944-     5.505  $      .33
14.31.55.COPYMCF,COMPILE,,,P.
14.31.55.NL  110000
14.31.55.RP        00000151  000000000770
14.32.01.NL     4400
14.32.01.RP  000000000155  000000001061
14.32.05.NL  110000
14.32.05.RP  000000000207  000000002031
14.32.05.MAX FILES 0005 MAX PRUS 0014008.
14.32.05.PP  008.016 SEC.
14.32.05.RP  000000000207  000000002031
14.32.05.CP USE  002.551 SEC    VALUE$  000.11
14.32.05.PP USE  014.849 SEC    VALUE$  000.04
14.32.05.CM USE  000.895 W-H    VALUE$  000.24
14.32.05.TOTAL COMPUTE VALUE AT RG2 $  000.39
14.34.50.,000037 PAGES PRINT, 001727 LINES PRINT, FOR $ 001.02 AT RG2,
```

BIBLIOGRAPHY

A.1 Abkin, Michael H. 1972. "Policy Making for Economic Development A System Simulation of the Agricultural Economy of Southern Nigeira." Staff Paper Series 72-4. Department of Agricultural Economics, Michigan State University, East Lansing.

A.2 _______, and Rossmiller, George E. 1972. "Sector Analysis and the General System Simulation Approach to Agricultural Development Planning." Paper presented at CENTO Workshop for Agricultural Planners, Islamabad, Pakistan, November 27-December 4.

A.3 Adams, D. W. and Singh, I. J. 1972. "Capital Formulation and the Firm-Household Decision Making Process." Economics and Sociology Occasional Paper No. 111. Department of Agricultural Economics and Rural Sociology, Ohio State University, Columbus.

A.4 _______, and Coward E. Walter, Jr. 1972. "Small-Farmer Development Strategies: A Seminar Report." Research and Training Network, the Agricultural Development Council, Inc., New York.

A.5 Adelman, Irma and Thorebecke, Erik, ed. 1966. The Theory and Design of Economic Development. Johns Hopkins Press, Baltimore.

A.6 Ahan, Coong Y. and Singh, I. J. 1973. "Comparative Policy Simulations: Economic Development in Brazil to 1985." Economics and Sociology Occasional Paper No. 169, Ohio State University, Columbus.

A.7 Alcantara, Reinaldo and Prato, Anthony A. 1973. "Returns to Scale and Input Elasticities for Sugarcane: The Case of Sao Paulo, Brazil," American Journal of Agricultural Economics, 55:577-83.

A.8 Allen, R. G. D. 1964. Mathematical Analysis for Economists. St. Martin's Press, New York.

A.9 Arrow, K. J., et al. 1961. "Capital-Labor Substitution and Economic Efficiency," Review of Economics and Statistics, 34:225-48.

A.10 Auer, Lordwig and Heady, Earl O. 1964. "The Contribution of Weather and Yield Technology to Change in U.S. Corn Production, 1939 to 1961," Weather and Our Food Supply. CAED Report 20, Iowa State University, Ames, Iowa.

B.1 Barker, Randolph. 1961. "Supply Function for Milk Under Varying Price Situation," Journal of Farm Economics, 43:651-58.

B.2 _______, 1971. "The Evolutionary Nature of the New Rice Technology," Food Research Institute Studies, 10:117-30. Stanford University, Stanford, California.

B.3 Bateman, Merrill J. 1969. "Supply Relations for Perennial Crops in the Less Developed Areas," in Wharton, Clifton R., Jr., Subsistence Agriculture and Economic Development, pp. 243-53. Aldine Publishing Co., Chicago.

B.4 Beckford, George L. "Strategies for Agricultural Development: Comment," Food Research Institute Studies, 11:149-54. Stanford University, Stanford, California.

B.5 Behrman, Jere R. 1966. "Price Elasticity of the Market Surplus of a Subsistence Crop," Journal of Farm Economics, 48:875-93.

B.6 Bieri, Jurg, et al. 1972. "Agricultural Technology and the Distribution of Welfare Gains," American Journal of Agricultural Economics, 54:801-8.

B.7 Binswanger, Hans P. 1974. "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution," American Journal of Agricultural Economics, 56:377-86.

B.8 Black, John D., and Bonnen, James T. 1965. "A Balanced United States Agriculture in 1985," National Planning Association. Special Report 42. Washington, D.C.

B.9 Blakeslee, Leroy L., et al. 1973. World Food Production, Demand and Trade. Iowa State University Press, Ames, Iowa.

B.10 Bonnen, James T. 1963. "Analysis of Long-Run Economic Projections for American Agriculture. Proceedings, Twelfth Annual Meeting, Agricultural Research Institute, October 14-15, 1963. Committee on Agricultural Policy, Agricultural Board on National Academy of Science, National Research Council, Washington, D.C.

B.11 _______, and Cromarty, William A. 1958. "The Structure of Agriculture." In Heady, Earl O., et al, Agricultural Adjustment Problems in a Growing Economy, pp. 109-29. Iowa State University Press, Ames, Iowa.

B.12 Bowden, E. 1970. "A Comparison of Predictions from Static and Dynamic Model of Farm Innovation," Rural Sociology, 35:253-60.

B.13 Boyne, David H. and Johnson, Glenn L. 1958. "A Partial Evaluation of Static Theory From Results of the Interstate Managerial Study," Journal of Farm Economics, 40:458-69.

B.14 Bradford, Lawrence A. and Johnson, Glenn L. 1964. Farm Management Analysis. John Wiley and Sons, Inc., New York.

B.15 Brake, John R. 1972. "Capital and Credit." In Ball, A. Gordon and Heady, Earl O., ed. Size, Structure and Future of Farms, Iowa State University Press, Ames, Iowa.

B.16 Brown, Murray. 1968. On the Theory and Measurement of Technological Change. Cambridge University Press, London.

B.17 Byerlee, Derek and Eicher, Carl K. 1972. "Rural Employment, Migration and Economic Development: Theoretical Issues and Empirical Evidence from Africa." Rural Employment Paper No. 1, Department of Agricultural Economics, Michigan State University, East Lansing.

B.18 ________. 1973. "Indirect Employment and Income Distribution in Effects of Agricultural Development Strategies: A Simulation Approach Applied to Nigeria." African Rural Employment Paper No. 9. Department of Agricultural Economics, Michigan State University, East Lansing.

C.1 Campbell, R. R. 1966. "A Suggested Paradigm of the Individual Adoption Process," Rural Sociology, 31:485-466.

C.2 Chattopadhyay, S. N. and Pareek, U. 1967. "Prediction of Multi-Practice Adoption Behavior from Some Psychological Varialbes," Rural Sociology, 32:324-33.

C.3 Chenery, Hollis B., ed. 1971. Studies in Development Planning. Harvard University Press, Cambridge.

C.4 Cochrane, Willard W. 1958. "Some Additional Views on Demand and Supply." In Heady, Earl O., et al, ed. Agricultural Adjustment Problems in a Growing Economy, pp. 94-106. Iowa State University Press, Ames, Iowa.

C.5 ________. 1958. Farm Prices, Myth and Reality. University of Minnesota Press, Minneapolis, Minn.

C.6 ________. 1965. The City Man's Guide to the Farm Problem. University of Minnesota Press, Minneapolis, Minn.

C.7 Computer Library on Agricultural Systems Simulation. 1974. Michigan State University, East Lansing.

C.8 Cooper, George R. and McGillen, Clare D.. 1967. Methods of Signal and System Analysis. Holt, Rinehart and Winston, Inc., New York.

C.9 Cownie, John, et al. 1970. "The Quantitative Impact of the Seed-Fertilizer Revolution in West Pakistan," Food Research Institute Studies, 9:57-95. Stanford University, Stanford, California.

C.10 Cromarty, William A. 1959. "The Farm Demand for Tractors, Machinery and Trucks," Journal of Farm Economics, 41:323-31.

D.1 Daines, Samuel R. 1972. "Partial Implications of the Analysis for Decision-Making in the Agricultural Sector." Analytical Working Document #6, Colombia Agricultural Sector Analysis. AID-LA/DR/SASS, Washington, D.C.

D.2 Dandekar, V. M. 1972. "Effectiveness in Agricultural Planning," Development Processes and Planning (No. 19) A/D/C Teaching Forum. Agricultural Development Council, Inc., New York.

D.3 Day, Richard H. 1963. Recursive Programming and Production Response. North-Holland Publishing Company, Amsterdam.

D.4 ________ and Singh, I. J. 1972. "A Dynamic Microeconomic Model of Agricultural Development." Social Systems Research Institute, 7135. University of Wisconsin, Madison.

D.5 Dean, Gerald W. and Heady, Earl O. 1958. "Change in Supply Response and Elasticity for Hog," Journal of Farm Economics, 40:845-60.

D.6 de Haen, Hartwig. 1973. "Preliminary User's Guide to the Recursive Linear Programming Resource Allocation Component of the Korean Agricultural Sector Model." KASS Working Paper 73-2. Michigan State University, East Lansing.

D.7 ____ and Lee, Jeung Han. 1972. Dynamic Model of Farm Resource Allocation for Agricultural Planning in Korea--Application of Recursive Programming within a General System's Simulation Approach. Agricultural Sector Analysis and Simulation Projects. Project Working Paper 72-1. Michigan State University, East Lansing.

D.8 Denison, E. F. 1962. "The Sources of Economic Growth in the United States." Supplementary Paper No. 13. Committee for Economic Development, New York.

D.9 Desaeyere, W., et al. 1967. Long-Term Development of Supply and Demand for Agricultural Products in Belgium, 1970-1975. Studiecentrum Voor Economisch En Sociaal Onderzoek, Prinsstraat 13, Antwerpen, Belgium

D.10 Dorner, Peter. 1971. "Needed Redirections in Economic Analysis for Agricultural Development Policy," American Journal of Agricultural Economics, 53:8-16.

D.11 Duloy, J. H., et al. 1974. "Agriculture and the Energy Crisis: A Case Study in Mexico," Paper presented at the AAEA Annual Meeting, Texas A & M University, College Station, Texas, August 18-21.

E.1 Edwards, Clark. 1959. "Resource Fixity and Farm Organization," Journal of Farm Economics, 41:747-59.

E.2 Eicher, Carl K., et al. 1970. "Employment Generation of African Agriculture." Institute of International Agriculture. College of Agriculture and Natural Resources, Research Report No. 9. Michigan State University, East Lansing.

E.3 Evenson, Robert. "The Green Revolution in Recent Development Experience," American Journal of Agricultural Economics, 56:387-93.

F.1 Falcon, Walter P. 1966. "Programming Models on the Planning of the Agricultural Sector, Comment," In Adelman, Irma and Thorebecke, Erik, ed. The Theory and Design of Economic Development. Johns Hopkins Press, Baltimore.

F.2 Feaster, J. G. 1968. "Measurement and Determinants of Innovativeness among Primitive Agriculturalists," Rural Sociology, 33:339-48.

F.3 Fernando, C. 1963. "Projections of Potential Supply--Tree Crops." FAO, Agricultural Planning Course, 1963, Agricultural Planning Studies, No. 4. Rome.

F.4 Ferris, John N. and Suh, Han Hyeck. 1971. "An Analysis of Supply Response on Major Agricultural Commodities in Korea," KASS Special Report 4, Michigan State University, East Lansing.

F.5 ________, et al. 1972. "Investment Priorities in the Korean Agricultural Sector." Korean Agricultural Sector Study Team. Michigan State University, East Lansing.

F.6 Fishel, Walter L. 1971. Resource Allocation in Agricultural Research. University of Minneosta Press, Minneapolis.

F.7 Fletcher, L. B., et al. 1970. Guatemala's Economic Development: The Role of Agriculture. Iowa State University Press, Ames, Iowa.

F.8 Fliegel, F. C., et al. 1968. "A Cross-National Comparison of Farmers' Perception of Innovation as Relative to Adaption Behavior," Rural Sociology, 33:437-49.

F.9 Fox, Karl. 1953. "The Analysis of Demand for Farm Products,' U.S. Department of Agriculture. Technical Bulletin 1081, Washington, D.C.

F.10 Forrester, J. W. 1961. Industrial Dynamics. Massachusetts Institute of Technology Press, Cambridge, Mass.

F.11 _______. 1968. Principles of Systems. Wright-Allen Press, Inc., Cambridge, Mass.

F.12 Frisch, Ragnar. 1959. "A Complete Scheme for Computing All Direct and Cross Demand Elasticities in a Model with Many Secotrs," Econometrica, 27:177-96.

G.1 Gittinger, J. Price. 1972. Economic Analysis of Agricultural Projects. Johns Hopkins Press, Baltimore.

G.2 Government of the Republic of Korea. 1971. The Third Five-Year Economic Development Plan. Seoul, Korea.

G.3 Goreux, Louis M. and Manne, Alan S. ed. 1973. Multi-Level Planning: Case Studies in Mexico. North-Holland Publishing Company, Amsterdam.

G.4 Griffin, Keith B. and Enos, John L. 1970. Planning Development. Addison-Wesley Publishing Co., London.

G.5 Griliches, Zvi. 1957. "Specification Bias in Estimates of Production Functions," Journal of Farm Economics, 39:8-20.

G.6 _______. 1957. "Hybrid Corn: An Exploration in the Ecoomics of Technological Change," Econometrica, October.

G.7 _______. 1958. "The Demand for Fertilizer: An Economic Inter-Pretation of a Technical Change," Journal of Farm Economics, 40:591-606.

G.8 _______. 1958. "Research Costs and Social Returns: Hybrid Corn and Related Innovation," Journal of Political Economy, 66:419-31.

G.9 _______. 1959. "The Demand for Inputs in Agriculture and a Derived Supply Elasticity," Journal of Farm Economics, 41:309-322.

G.10 _______. 1959. "Distributed Lags, Disaggregation, and Regional Demand Functions for Fertilizer," Journal of Farm Economics, 41:90-102.

G.11 _______. 1960. "Estimation of the Aggregate U.S. Farm Supply Function," Journal of Farm Economics, 42:282-93.

G.12 _______. 1963. "The Sources of Measured Productivity Growth: U.S. Agriculture, 1900-1960," Journal of Political Economy, 71:331-46.

H.1 Hahn, F. H. and Mattews, R. G. O. 1964. "The Theory of Economic Growth: A Survey," Economic Journal, 74:779-902.

H.2 Halter, A. N., et al. 1970. "Simulating a Developing Agricultural Economy: Methodology and Planning Capacity," American Journal of Agricultural Economics, 52:272-84.

H.3 Halvorson, Harlow W. 1958. "The Response of Milk Production to Price," Journal of Farm Economics, 41:1101-13.

H.4 Harris, John R. and Todaro, Michael P. 1970. "Migration, Unemployment and Development: A Two-Sector Analysis," American Economic Review, 60:126-42.

H.5 Hathaway, Dale E. 1963. Government and Agriculture. MacMillan Company, New York.

H.6 Havens, A. E. 1965. "Increasing the Effectiveness of Predicting Innovativeness," Rural Sociology, 30:150-65.

H.7 Haver, Cecil B. 1958. "Institutional Rigidities and Other Imperfections in the Factor Markets," In Heady, Earl O., et al., ed. Agricultural Adjustment Problems in a Growing Economy, Iowa State University, Ames, Iowa.

H.8 Hayami, Y. 1964. "Demand for Fertilizer in the Course of Japanese Agricultural Development," Journal of Farm Economics, 46:766-79

H.9 _______ and Ruttan, Vernon W. 1971. Agricultural Development: An International Perspective. Johns Hopkins Press, Baltimore.

H.10 Heady, Earl O. 1949. "Basic Economic and Welfare Aspects of Farm Technological Change," Journal of Farm Economics, 31: 293-316.

H.11 _______. 1960. Economics of Agricultural Production and Resource Use. Prentince-Hall, Inc., Englewood Cliffs, N.J.

H.12 _______. 1961. "Public Purpose in Agricultural Research and Education," Journal of Farm Economics, 43:566-81.

H.13 _______. 1961. "Uses and Concepts in Supply Analysis." In Heady, Earl O., et al., ed. Agricultural Supply Functions-Estimating Techniques and Interpretation, Iowa State University Press, Ames, Iowa.

H.14 ______. 1965. Agricultural Policy Under Economic Development. Iowa State University, Ames, Iowa.

H.15 ______. 1966. "Priorities in the Adoption of Improved Farm Technology." In Iowa State University Center for Agricultural and Economic Development. Economic Development of Agriculture, Iowa State University Press, Ames, Iowa.

H.16 ______ and Candler, Wilfred. 1958. Linear Programming Method. Iowa State University Press, Ames, Iowa.

H.17 ______. 1968. "Processes and Priorities in Agricultural Development." In McPherson, W. W., ed. Economic Development of Tropical Agriculture, University of Florida Press, Gainesville, Fla.

H.18 ______ and Dillon, John L. 1964. Agricultural Production Functions. Iowa State University Press, Ames, Iowa.

H.19 ______ and Tweeten, Luther, G. 1963. Resource Demand and Structure of the Agricultural Industry. Iowa State University Press, Ames, Iowa.

H.20 ______ and Yeh, Martin H. 1959. "National and Regional Demand Functions for Fertilizer," Journal of Farm Economics, 41: 332-48.

H.21 ______, ed. 1971. Economic Models and Quantitative Methods for Decisions and Planning in Agriculture. Iowa State University Press, Ames, Iowa.

H.22 ______. 1955. "The Supply of Farm Products Under Conditions of Full Employment," American Economic Review, 45:228-38.

H.23 Herdt, R. W. and Mellor, John W. 1964. "The Contrasting Response of Rice to Nitrogen: India and the United States," Journal of Farm Economics, 46:150-60.

H.24 Hertford, Raed. 1971. "Sources of Change in Mexican Agricultural Production 1940-65," Foreign Agricultural Economic Report No. 73, Economic Research Service, U.S.D.A., Washington, D.C.

H.25 Hirshman, Algert O. 1958. The Strategy of Economy Development. Yale University Press, New Haven, Conn.

H.26 Holland, E. P. 1970. "Discussion: Macro-Simulation Models," American Journal of Agricultural Economics, 52:284-286.

H.27 Hsieh, S. C. and Ruttan, Vernon W. 1967. Environmental, Technological, and Institutional Factors in the Growth of Rice Production: Philippines, Thailand and Taiwan," Food Research Institute Studies, 7:307-42.

H.28 Huh, Sin H. and Lee, Jeung Han. 1971. "Feed Marketing, Livestock-Feed Price Cycles and Livestock Supply Functions," AERI, Research Report Series No. 35. Agricultural Economics Research Institute, Ministry of Agriculture and Forestry, Seoul, Korea.

J.1 Jensen, Harold R. 1958. "Technological Research in Relation to Adjustment. In Heady, Earl O., et al., ed. Agricultural Adjustment Problems in a Growing Economy. Iowa State University Press, Ames, Iowa.

J.2 Johnson, Glenn L. 1956. "Classification and Accounting Problems in Fitting Production Functions to Farm Record and Survey Data," In Heady, Earl O., et al., ed. Resource Productivity, Returns to Scale, and Farm Size, Iowa State University Press, Ames, Iowa.

J.3 _______. 1975. "Sources of Expanded Agricultural Production," Policy for Commerical Agriculture--Its Relation to Economic Growth and Stability, Joint Economic Committee. 85th Congress of the U.S., November 22.

J.4 _______. 1958. "Supply Function--Some Facts and Notions," In Heady, Earl O., et al., ed. Agricultural Adjustment Problems in a Growing Economy, Iowa State University Press, Ames, Iowa.

J.5 _______. 1960. "The State of Agricultural Supply Analysis," Journal of Farm Economics, 42:435-52.

J.6 _______. 1960. "Review of Nerlove," Agricultural Economics Research, 12:25-8.

J.7 _______. 1960. "Value Problems in Farm Management," Journal of Agricultural Economics, 14:13-31.

J.8 _______. 1961. "Budgeting and Engineering Analyses of Normative Supply Functions," In Heady, Earl O., et al., ed. Agricultural Supply Functions--Estimating Techniques and Interpretations, Iowa State University Press, Ames, Iowa.

J.9 _______. 1970. "Discussion: Macro-Simulation Models," American Journal of Agriucultral Economics, 52:286-8.

J.10 _______. 1970. "The Role of the University and Its Economists in Economic Development." Presented as the J. S. McLean Visiting Professor Lecture. Department of Agricultural Economics, University of Guelph, Canada.

J.11 _______. 1972. "Alternatives to the Neoclassical Theory of the Firm," American Journal of Agricultural Economics, 54:295-303.

J.12 ________. Undated paper. "A Review of Work Involving Traditional Projections and Modern Computer Simulation." Presented at Dijon Meeting of TACAC. Michigan State University, East Lansing.

J.13 ________, et al. 1961. A Study of Managerial Processes of Midwestern Farmers. Iowa State University Press, Ames, Iowa.

J.14 ________, et al. 1969. "Strategies and Recommendation for Nigerian Rural Development 1966/1985." Consortium for the Study of Nigerian Rural Development. CSNRD 33. Michigan State University, East Lansing.

J.15 ________, and Zerby, Lewis K. 1973. What Economists Do About Values. Department of Agricultural Economics, Center for Rural Manpower and Public Affairs, Michigan State University, East Lansing,

J.16 ________, ed. 1972. The Overproduction Trap in U.S. Agriculture. Johns Hopkins University Press, Baltimore.

J.17 ________ and Hardin, Lowell S. 1955. "Economics of Forage Evaluation." Purdue Agricultural Experiment Station Bulletin 623. Lafayette, Indiana.

J.18 Johnson, Sherman E. 1965. "Combining Knowledge, Incentives and Means to Accelerate Agricultural Development." In Iowa State University, Center for Agricultural and Economic Development. Economic Development of Agriculture, Iowa State University Press, Ames, Iowa.

J.19 Johnston, Bruce F. and Cownie, John. 1969. "The Seed-Fertilizer Revolution and Labor Force Absorption," American Economic Review, 59:569-82.

J.20 ________ and Southworth, Herman M. 1967. "Agricultural Development: Problems and Issues," In Southworth, Hermand M. and Johnston, Bruce F., Agricultural Development and Economic Growth, Cornell University Press, Ithaca, N.Y.

J.21 ________ and Mellor, John W. 1961. "The Role of Agriculture in Economic Development," American Economic Review, 51:566-93.

J.22 Jorgenson, Dale W. 1961. "The levelopment of a Dual Economy," Economic Journal, 71_309-34.

K.1 Kae, Bong Myung, Lee, Jeung Il, and Lee, Jeung Han. 1968. "A Study on Optimum Use of Fertilizer Resource in Rape Production in Korea," Journal of Institute for Agricultural Resource Utilization, Chinju Agricultural College, Chinju, Korea.

K.2 Kehrberg, Earl W. 1961. "Determination of Supply Functions from Cost and Production Functions." In Heady, Earl O., et al., ed. Agricultural Supply Functions--Estimating Techniques and Interpretation, Iowa State University Press, Ames, Iowa.

K.3 Kelley, Allen C., et al. 1972. Dualistic Economic Development: Theory and History. University of Chicago Press, Chicago.

K.4 Kim, Sang Gee. 1971. "The Impact of PL 480 Shipments on Price and Domestic Production of Foodgrains in Korea," Journal of Agricultural Economics (Korea), 8:72-85.

K.5 Kislev, Yaav, et al. 1973. "The Process of an Innovation Cycle," American Journal of Agricultural Economics, 55:28-37.

K.6 Knight, Dale A. 1961. "Evaluation of Time Series as Data for Estimating Supply Parameters." In Heady, Earl O. et al., ed. Agricultural Supply Functions--Estimating Techniques and Interpretation, Iowa State University Press, Ames, Iowa.

K.7 Kravis, I. B. 1970. "Trade as a Handmaiden of Growth: Similarities Between the Nineteenth and Twentieth Centuries," Economic Journal, December.

K.8 Kresge, David T. 1970. "Discussion: Macro-Simulation Models," American Journal of Agricultural Economics, 52:288-90.

K.9 Krishna, Raj. 1962. "A Note on the Elasticity of the Marketable Surplus of a Subsistence Crop," Indian Journal of Agricultural Economics, 17:79-84.

K.10 ________. 1967. "Agricultural Price Policy and Economic Development." In Southwarth, Herman M. and Johnson, Bruce F., ed. Agricultural Development and Economic Growth, Cornell University Press, Ithaca, New York.

L.1 Lau, Lawrence J. and Yotopoulas, Pan A. 1971. "A Test for Relative Efficiency and Application to Indian Agriculture," American Economic Review, 61:94-109.

L.2 ________. 1972. "Profit, Supply and Factor Demand Functions," American Journal of Agricultural Economics, 54:11-18.

L.3 Learn, Elmer W. and Cochrane, Willard W. 1961. "Regression Analysis of Supply Functions Undergoing Structural Change." In Heady, Earl O., et al., ed. Agricultural Supply Functions--Estimating Techniques and Interpretation, Iowa State University, Ames, Iowa.

L.4 Lee, Jeung H. 1969. "Factor Demand and Product Supply Functions and Optimal Allocation Patterns Derived from Experimental Fertilizer Production Functions," Journal of the Institute for Agricultural Resource Utilization. Chinju National Agricultural College, Chinju, Korea, 3:1-68.

L.5 ________. 1972. "Potentials of Hog Supply: Adaptability of Some New Production Factors Related to Hog Production in Korea," Journal of the Institute for Agricultural Resource Utilization, Chinju. National Agricultural Colelge, Chinju, Korea, 6:159-204.

L.6 ________. 1963. "On Problems of Foodgrain Production," (in Korean). Research Bulletin of Chinju Agricultural College, 2:119-29. Chinju, Korea.

L.7 ________ and Chung, Chang Hoon. 1966. "A Study of Substitution Relationship Between Mixed Concentrate and Sweet Potato Ensilage in Pork Production," Research Bulletin of Chinju Agricultural College, 5:29-38, Chinju, Korea.

L.8 ________ and Kim, Hoo Keun. 1970. "Optimum Combination of Winter Crop Enterprises in Rice Paddy in Honan District--Application of Linear Programming," Journal of Institute for Agricultural Resource Utilization, Chinju Agricultural College, 4:21-26. Chinju, Korea.

L.9 ________. 1973. "A Suggested Dynamic Input-Output Model for Policy Simulation," Unpublished Mimeograph. Department of Agricultural Economics, Michigan State University, East Lansing.

L.10 ________. 1973. "Farm Resource Allocation Submodel of a Generalized Systems Simulation Model for Korean Agricultural Sector Analysis." Discussion paper for World Bank Colloquim on Advanced Methodologies for Agricultural Investment and Policy Analysis, January 29-39.

L.11 ________, et al. 1973. "El Salvador Credit Union Development Project," Unpublished mimeograph. Department of Agricultural Economics, Michigan State University, East Lansing.

L.12 Lee, Teng-hui. 1971. Intersectoral Capital Flows in the Economic Development of Taiwan, 1895-1960. Cornell University Press, Ithaca.

L.13 Lehker, John N. and Manetsch, Thomas J. 1971. Systems Analysis of Development in Northeast Brazil: The Feasibility of Using Simulation to Evaluate Alternative Systems of Beef Production in Northeast Brazil." Technical Report G-13. Midwest Universities Consortium on International Affairs, Division of Engineering Research, Michigan State University, East Lansing.

L.14 Leibenstein, Harvey. 1963. Economic Backwardness and Economic Growth. John Wiley and Sons, Inc., New York.

L.15 Lele, Uma J. and Mellor, John W. "Estimates of Change and Causes of Change in Food Grains Production, India, 1949-50 to 1960-61." Cornell International Agricultural Development Bulletin 2. Cornell University, Ithaca, N.Y.

L.16 Lewis, W. A. 1954. "Economic Development with Unlimited Supplies of Labor." Manchester School of Economics and Social Studies 22:139-91.

L.17 _______. 1972. "Reflection on Unlimited Labor." In Luis Eugenio Di Marco, ed. International Economics and Development, Academic Press, New York.

L.18 _______. 1955. The Theory of Economic Development. Unwin, London.

L.19 Llewellyn, Robert W. 1965. Fordyn: An Industrial Dynamics Simulator. Raleigh, North Carolina. Privately printed.

L.20 Lu, Yao-Chi and Fletcher, Lehman B. 1968. "A Generalization of the CES Production Function," Review of Economics and Statistics, 50:449-52.

L.21 _______. 1974. "A Production Function Approach to Measuring Productivity Growth in U.S. Agriculture." Paper presented at the AAEA Annual Meeting. Texas A&M University, College Station, Texas, August 18-21.

M.1 Malone, Carl C. 1965. "Some Responses of Rice Farmers to the Package Program in Tanjore District, India," Journal of Farm Economics, 47:256-69.

M.2 _______. 1971. "Improving Opportunities for Low-Income Farm Occupied People: Some Indian Experiences." Paper presented in A/D/C Seminar on Small-Farmer Development Strategies, Ohio State University, Columbus, September 13-15.

M.3 Manetsch, Thomas J., et al. 1968. "Computer Simulation Analysis of a Program for Modernizing Cotton Production in Northeast Brazil." Systems Analysis of Development in Northeast Brazil. Working Paper No. 3, Systems Science Group. College of Engineering, Michigan State University, East Lansing.

M.4 _______, et al. 1971. "A Generalized Simulation Approach to Agricultural Sector Analysis with Special Reference to Nigeria." Michigan State University, East Lansing.

M.5 _____ and Lenchner, Sanford L. 1971. "Systems Analysis of Development in Northeast Brazil: The Feasibility of Using Simulation to Evaluate Alternative Policies for Development of the Brazilian Textile Industry." Technical Report G 13. Midwest University Consortium on International Affairs, Division of Engineering Research, Michigan State University, East Lansing.

M.6 _______ and Park, Gerald L. 1970. System Analysis and Simulation with Application to Economic and Social Systems. Preliminary Edition. Department of Electrical Engineering and System Science, Michigan State University, East Lansing.

M.7 _______. Undated. "Use of the VDEL Subroutine to Simulate Project Implementation in Economic Development." Unpublished Paper. Michigan State University, East Lansing.

M.8 Meadows, Dennis L. 1970. Dynamics of Commodity Production Cycles. Wright-Allen Press, Inc., Cambridge, Mass.

M.9 Meier, Gerald M. 1968. The International Economics of Development. Harpers Row, Publishers, New York.

M.10 Mellor, John W. 1966. The Economics of Agricultural Development. Cornell University Press, Ithaca.

M.11 _______. 1967. "Toward a Theory of Agricultural Development." In Southworth, Herman M. and Johnston, Bruce F., ed. Agricultural Development and Economic Growth, Cornell University Press, Ithaca, New York.

M.12 _______. 1969. "The Subsistence Farmer in Traditional Economies." In Wharton, Clifton R., Jr., ed. Subsistence Agriculture and Economic Development, Aldine Publishing Co., Chicago.

M.13 _______. 1969. "Production Economics and the Modernization of Traditional Agriculture," Australian Journal of Agricultural Economics, 13:25-35.

M.14 _______. 1972. "Models of Economic Growth and Land Augmenting Technological Change in Food Grain Products." Paper presented at International Economic Association Conference on the Place of Agriculture in the Development of Underdeveloped Countries. Bad Gadesberg, Germany, August 26-September 4.

M.15 Michigan State University Agricultural Sector Simulation Team. 1973. "System Simulation of Agricultural Development: Some Nigerian Policy Comparisons," American Journal of Agricultural Economics, 55:404-19.

M.16 Mighell, Ronald L. and Black, John D. 1951. Interregional Competition in Agriculture with Special Reference to Dairy Farming in the Lake States and New England. Harvard University Press, Cambridge, Mass.

M.17 Mikesell, Raymond F. 1968. The Economics of Foreign Aid. Aldine Publishing Co., Chicago.

M.18 Miller, S. I. and Halter, A. N. 1973. "Systems-Simulation in a Practical Policy-Making Setting: The Venezuelan Cattle Industry," American Journal of Agricultural Economics, 55:420-32.

M.19 Mitroff, Ian I. and Turoff, Murry. 1973. "Technological Forecasting and Assessment: Science and/or Mythology?" Technological Forecasting and Social Changes, 5:113-34.

M.20 Moseman, Albert H. 1965. "Research Needed for Technological Knowledge in Agricultural Development." In Iowa State University Center for Agricultural and Economic Development. Economic Development of Agriculture, Iowa State University Press, Ames, Iowa.

M.21 ________. 1970. Building Agricultural Research Systems in the Developing Nations. Agricultural Development Council, Inc., New York.

M.22 Mosher, A. T. 1965. "Research Needed on the Development Process for Agriculture." In Iowa State University Center for Agricultural and Economic Development. Economic Development of Agriculture, Iowa State University Press, Ames, Iowa.

M.23 ________. 1966. Getting Agriculture Moving. Praeger, New York.

M.24 ________. 1969. Creating a Progressive Rural Structure. Agricultural Development Council, Inc., New York.

M.25 ________. 1972. "Projects of Integrated Rural Development." A/D/C Reprint. The Agricultural Development Council, Inc., New York.

M.26 Moulik, T. K. and Lokhande, M. R. 1969. "Value Orientation of Northern Indian Farmers and Its Relation to Adoption of Farm Practice," Rural Sociology, 34:374-81.

M.27 Mudahar, M. S. 1973. "Dynamic Models of Agricultural Development with Demand Linkages." Occasional Paper No. 59, Department of Agricultural Economics, Cornell University, Ithaca, N.Y.

M.28 Myint, Mla. 1969. The Economics of the Developing Countries. Praeger Publishers, New York.

M.29 Myren, Delbert T. 1971. "The Puebla Project: A Developmental Strategy for Low Income Farmers." Paper presented in A/D/C Seminar on Small-Farmer Development Strategies. Ohio State University, Columbus, September 13-15.

N.1 Nakajima, Chihiro. 1969. "Subsistence and Commercial Family Farms: Some Theoretical Models of Subjective Equilibrium." In Wharton, Clifton R., Jr., ed. Subsistence Agriculture and Economic Development, Aldine Publishing Co., Chicago.

N.2 National Council of Applied Economic Research. 1962. Long Term Projections of Demand for and Supply of Selected Agricultural Commodities, 1960-61 to 1975-76. New Delhi, India.

N.3 Naylor, Thomas H. 1970. "Policy Simulation Experiments with Macroeconomic Models: The State of the Art," American Journal of Agricultural Economics, 52:263-70.

N.4 ______. 1971. Computer Simulation Experiments with Models of Economic Systems. Johns Wiley & Sons, Inc., New York.

N.5 Nelson, Richard R. 1964. "Aggregate Production Functions and Medium Range Growth Projections," American Economic Review, 54: 575 606.

N.6 Nerlove, Marc. 1958. The Dynamics of Supply: Estimate of Farmers' Response to Price. Johns Hopkins Press, Baltimore.

N.7 ______. 1961. "Time-Series Analysis of the Supply of Agricultural Products." In Heady, Earl O., et al., ed. Agricultural Supply Functions--Estimating Techniques and Interpretations, Iowa State University Press, Ames, Iowa.

N.8 ______ and Backman, Kenneth L. 1960. "The Analysis of Changes in Agricultural Supply: Problems and Approaches," Journal of Farm Economics, 42:331-54.

N.9 Nicholls, William H. 1964. "The Place of Agriculture in Economic Development," In Eicher, Carl and Witt, Lawrence, ed. Agriculture in Economic Development, McGraw-Hill Book Co., New York.

N.10 Nurke, Ragner. 1957. Problems of Capital Formulation of Underdeveloped Countries. Oxford University Press, New York.

O.1 OECD. 1972. Development Cooperation: 1972 Review. OECD, Paris.

O.2 Ojala, E. M. 1967. "The Programming of Agricultural Development." In Southworth, Herman M. and Johnston, Bruce F., ed. Agricultural Development and Economic Growth, Cornell University Press, Ithaca, N.Y.

O.3 Olayide, S. O. 1972. "Improving the Data and Information Base." Paper presented A/D/C Conference on the General Systems Analysis Approach in Agricultural Sector Analysis and Planning. Airlie House, Virginia, May 1-3.

O.4 Oshima, Harry T. 1971. "Labor Absorption in East and Southeast Asia: A Summary with Interpretation of Post War Experience," Malayan Economic Review, 16:55-77.

O.5 _______. 1971. "Labor-Force'Explosion' and the Labor-Intensive Sector in Asian Growth," Economic Development and Cultural Change, 19:161-83.

P.1 Parker, F. W. 1965. "Priorities in Agricultural Development and Investment." In Iowa State University Center for Agricultural and Economic Development, Economic Development of Agriculture, Iowa State University, Ames, Iowa.

P.2 Parvin, D. W., Jr. 1973. "Estimation of Irrigation Response from Time-Series Data on Nonirrigated Crops," American Journal of Agricultural Economics, 55:73-6.

P.3 Pen, J. B., et al. 1974. "Structural Input-Output Modeling of the Food and Fiber System Under Conditions of Fuel Scarcity." Paper presented at the AAEA Annual Meeting, Texas A & M University, College Station, Texas, August 18-21.

P.4 Perry. A., et al. 1967. "The Adoption Process: S Curve or J Curve?" Rural Sociology, 32:220-22.

P.5 Peterson, Willis L. 1971. "The Returns to Investment in Agricultural Research in the United States." In Fishel, Walter L., ed. Resource Allocation in Agricultural Research, University of Minneosta Press, Minneapolis, Minn.

P.6 Posado, Alvaro. 1974. "A Simulation Analysis of Policies for the Northern Colombia Beef Cattle Industry." Unpublished Ph.D. disseration, Michigan State University, East Lansing.

Q.1 Quance, Leroy. 1967. "Farm Capital: Use, MVP's and Capital Gains or Losses, United States 1917-64." Ph.D. disseration, Michigan State University, East Lansing.

R.1 Ranis, Tustav and Fli, John C. H. 1964. "A Theory of Economic Development." In Eicher, Carl and Witt, Lawrence, ed., Agriculture in Economic Development for Latin America, St. Martin's Press, New York.

R.2 Ray, Daryll E. and Heady, Earl O. 1972. "Government Farm Programs and Commodity Interaction: A Simulation Analysis," American Journal of Agricultural Economics, 54:578-90.

R.3 _______. 1974. "Simulated Effects of Alternative Policy and Economic Environments on U.S. Agriculture." CARD Report 46T, Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa.

R.4 Reynolds, Lloyd G. 1969. "Economic Development with Surplus Labor: Some Complications," Oxford Economic Papers, 21:89-103.

R.5 Rogers, Everett M. and Shoemaker, F. Floyd. 1971. Communication of Innovation A Cross-Cultural Approach. The Free Press, New York.

R.6 Rosenstein-Radan, Paul N. 1961. "Notes on the Theory of the 'Big Push'," in Ellis, Howard S. and Wallick, Hencry C., ed. Economic Development for Latin America, St. Martin's Press, New York.

R.7 Rossmiller, George E., et al. 1972. "Korean Agricultural Sector Analysis and Recommended Development STrategies, 1971-1985" Korean Agricultural Sector Study Team. Michigan State University, East Lansing.

R.8 Ruttan, Vernon W. 1960. "Research on the Economics of Technological Change in American Agriculture," Journal of Farm Economics, 42:735-754.

R.9 _______. 1965. The Economic Demand for Irrigated Areas. Johns Hopkins Press, Baltimore.

R.10 _______. 1968. "Strategy for Increasing Rice Production in Southeast Asia." In McPherson, W. W., ed. Economic Development of Tropical Agriculture, University of Florida Press, Gainesville, Fla.

R.11 _______ and Hayami, Y. 1972. "Strategies for Agricultural Development," Food Research Institute Studies, 11:111-28. Stanford University, Stanford, Calif.

R.12 _______ and Stout, T. T. 1960. "Regional Differences in Factor Share in American Agriculture, 1925-57," Journal of Farm Economics, 42:52-68.

S.1 Schaller, W. Neil. 1969. "Discussion: The Supply Function in Agriculture Revisited," American Journal of Agricultural Economics, 51:367-9.

S.2 Schultz, Theodore W. 1964. Transforming Traditional Agriculture. Yale University Press, New Haven.

S.3 ________. 1971. "Knowledge, Agriculture and Welfare." Papere presented at Pugwash 21st Conference Meeting at Sincia, Romania, August 25-31.

S.4 ________. 1971. "The Allocation of Research to Research." In Fishel, Walter L., ed. Resource Allocation in Agricultural Research, University of Minnesota Press, Minneapolis, Minn.

S.5 Seers, Dodley. 1970. "The Meaning of Development." A/D/C Reprint. Agricultural Development Council, Inc., N.Y.

S.6 Seol, In Joon. 1972. "Supply Response to Expected Price of Rice in Korea," Journal of Agricultural Economics (Korean), 9:72-78.

S.7 Shapiro, Harold T. 1973. "Is Verification Possible? The Evaluation of Large Econometric Models," American Journal of Agricultural Economics, 55:250-8.

S.8 Shechter, Mordechai and Heady, E. O. 1970. "Response Surface Analysis and Simulation Model in Policy Choices," American Journal of Agricultural Economics, 52:41-50.

S.9 Sidhu, Surjit S. 1974. "Economics of Technical Change in Wheat Production in the Indian Punjab," American Journal of Agricultural Economics, 56:217-26.

S.10 Solo, Robert M. 1956. "A Contribution to the Theory of Economic Growth," Quarterly Journal of Economics, 20:65-94.

S.11 ________. 1957. "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, 30:312-20.

S.12 ________. 1962. "Technical Progress, Capital Formulation and Economic Growth," American Economic Review, 52:76-86.

S.13 Smith, Victor E. 1955. "Perfect vs. Discontinuous Input Market: A Linear Programming Analysis," Journal of Farm Economics, 37:538-45.

S.14 Srivastava, Uma K. and Heady, Earl O. 1973. "Technological Change and Relative Factor Share in Indian Agriculture: An Empirical Analysis," American Journal of Agricultural Economics, 55:509-14.

S.15 Staniforth, Sydney D. and Diesslin, Howard G. 1961. "Summary and Conclusions," In Heady, Earl O., et al., ed. Agricultural Supply Functions--Estimating Techniques and Interpretation, Iowa State University Press, Ames, Iowa.

S.16 Stern, Robert M. 1965. "Malayan Rubber Production, Inventory Holdings and the Elasticity of Export Supply," Southern Economic Journal, 31:314-23.

S.17 Stevens, Robert D. 1971. "Comilla Rural Development Program--Results from East Pakistan for International Testing." Paper presented in A/D/C Seminar on Small-Farmer Development Strategies, Ohio State University, Columbus, Sepbember 13-15.

S.18 Sung, Bai Y., et al. 1973. "Projection of the Demand for Fertilizer--Time Series Data Analysis," Journal of Agricultural Economics (Korean), 15:21-32.

T.1 Talpaz, Hovov. 1974. "Multi-Frequency Cobweb Model: Decomposition of the Hog Cycle," American Journal of Agricultural Economics, 56:38-49.

T.2 Thorbecke, Erik. 1973. "Sector Analysis and Models of Agriculture in Developing Countries," Food Research Institute Studies, 12:73-89, Stanford University, Stanford, Calif.

T.3 Todaro, Michael P. 1971. Development Planning: Models and Methods. Oxford Unviersity Press, London.

T.4 Tom, A. El. 1964 "Projections of Agricultural Production-Seasonal Crops," FAO Agricultural Planning Course 1963, Agricultural Planning Sutdies No. 4, Rome.

T.5 Tweeten, Luther G. and Quance, C. Leroy. 1969. "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches," American Journal of Agricultural Economics, 51:342-52.

T.6 Tyner, Fred M. and Tweeten, Luther G. 1965. "A Methodology for Estimating Production Parameters," Journal of Farm Economics, 47:1462-7.

T.7 ________. 1968. "Simulation as a Method of Appraising Farm Programs," American Journal of Agricultural Economics, 50:66-81.

U.1 UNCTAD, Commodity Division. 1970. "Econometric Analysis of the World Rubber Market." Draft, Geneva.

V.1 Vaurs, Rene, Condos, Apostolos, and Goreux, Louis. 1971. "A Programming Model of the Ivory Coast." Development Research Center, IBRD, Washington, D.C.

V.2 Vernon, Raymond. 1966. "Comprehensive Model-Building in the Planning Process: The Case of the Less-Developed Economies," Economic Journal, 76:57-69.

V.3 Vincent, Warren H., ed. 1962. Economics and Management in Agriculture. Prentice-Hall, Inc., Englewood Cliffs, N.J.

W.1 Wah, F. Chang Kwang. 1962. "Economic Aspects of Supply of Malayan Rubber." Rural Social Science Monograph--Malayan Series No. 3. Council on Economic and Cultural Affairs, Inc., New York.

W.2 Wharton, Clifton R., Jr. 1964. "Malayan Rubber Supply Conditions," A/D/C Reprint No. 3. Agricultural Development Council, Inc., New York.

W.3 ________. 1969. "The Green Revolution: Cornucopia or Pandora's Box?" Foreign Affairs, 47:465-76.

W.4 Wipe, Larry J. and Bawden, D. Lee. 1969. "Reliability of Supply Equations Derived From Production Function," American Journal of Agricultural Economics, 51:170-8.

W.5 Wood, Garland P. 1972. "Public Institutions: Their Response Characteristics to Agricultural Development Programs in the LDC's." Paper presented at the Purdue Workshop on Small-Farm Agriculture, November, Michigan State University, East Lansing.

Y.1 Yamado, Subura. "Changes in Output and in Conventional and Non-conventional Inputs in Japanese Agriculture Since 1880," Food Research Institute, Studies, 7:371-413.

Y.2 Yotopoulos, Pau A. 1968. "On Efficiency of Resource Utilizaton in Subsistence Agriculture," Food Research Institute Studies, 8:125-35. Stanford University, Stanford, Calif.

Z.1 Zarembka, Paul. 1972. Toward a Theory of Economic Development. Holden-Day, Ind., San Francisco, Calif.